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IMPROVING THE AGRONOMICS AND FEED VALUE OF KOCHIA

Final Report

E. Coxworth, D. Green and J.A. Kernan
Editors

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FINAL REPORT

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EXECUTIVE SUMMARY

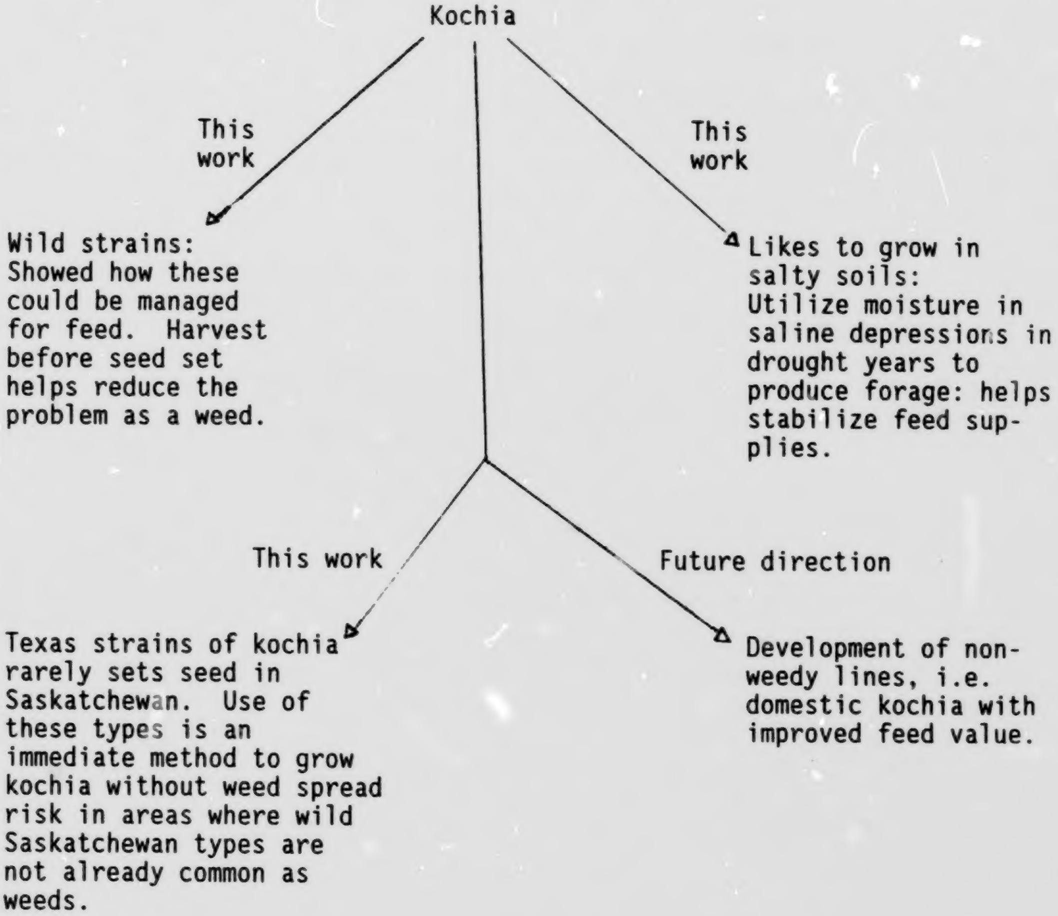
Our research found that the following steps were important in order to grow and feed kochia successfully:

- Seed kochia shallowly into a firm seed bed on cultivated ground.
- Fertilize with modest levels of N and P fertilizer, e.g., 50 kg N ha^{-1}, 20 kg P_2O_5 ha^{-1}.
- Harvest at the late bud to early flower stage.
- Crimp the hay to hasten drying.
- Feed at no more than 50% of the ration to pregnant beef cows.
- Have kochia feed analyzed for nitrate and oxalate as a precaution.

Kochia is a very common annual wild plant (weed) on disturbed saline soil throughout southern Saskatchewan. A three year research and development project was conducted to learn how best to manage, control, and utilize this wild plant for forage to feed to cattle. This project was planned as the first stage in development of non-weedy strains of this plant as a domestic crop. In the short term, increased use of the immature wild plants for forage should reduce kochia's problem as a weed, since kochia spreads entirely due to seed production.

The general strategy for use of kochia, and its development into a crop, is shown in figure 1.

Figure 1. General strategy for the development of kochia into a new forage crop for saline soils



Wild strains: Showed how these could be managed for feed. Harvest before seed set helps reduce the problem as a weed.

Likes to grow in salty soils: Utilize moisture in saline depressions in drought years to produce forage: helps stabilize feed supplies.

Texas strains of kochia rarely sets seed in Saskatchewan. Use of these types is an immediate method to grow kochia without weed spread risk in areas where wild Saskatchewan types are not already common as weeds.

Development of non-weedy lines, i.e. domestic kochia with improved feed value.

Highlights of the research and development findings:

- A survey of 54 farmers, each with a least several years experience using kochia, showed that most farmers were harvesting wild stands which grew on cultivated saline soils on their farms. Kochia dominated planted crops in severely saline areas but was replaced by crop (usually barley) on less saline areas. Harvesting kochia early (at late bud or early flowering) gave better forage. Farmers did not feed cattle more than 50% kochia in the diet. Most fed 20-40%. At these percentages of the total feed no farmers encountered any problems feeding kochia, either with the mother cows, or the calves produced. The farmers were almost all very enthusiastic about kochia but wanted more information on how best to grow and utilize it.

- Kochia needs disturbed soil, i.e. cultivated, to grow well. The small seed needs to be planted shallowly into a firm seed bed, free of mustard family weeds, such as flixweed and stinkweed, which are toxic to kochia. Farmers and researchers have developed several methods to obtain successful seeding. Seeding rates are low (less than 4 kg ha^{-1}) and seed costs per hectare are thus low also.

- Kochia forage yields, and protein content, were improved by the use of nitrogen fertilizer (kochia is not a legume). Use of too much nitrogen fertilizer led to nitrate accumulation in kochia, on occasion to serious levels. Kochia protein contents up to 20% were obtained. Farmers samples ranged from about 8-15% generally.

- Oxalate (another possible toxic constituent of plants) built up in kochia as protein levels increased. A spectroscopic method was developed to quickly analyze kochia feed samples for oxalate. Most farmers samples did not contain seriously high levels of oxalate, particularly when kochia was kept at less than 50% of the animals' ration.

- Kochia accumulated larger amounts of a number of minerals, e.g. potassium, sodium, calcium, magnesium, sulfate, than conventional hays, particularly when grown on saline soil. Farmers reported they had generally solved potential laxative problems from these minerals by diluting kochia with other feeds*.

- Feeding trials with steers showed that kochia could be fed at amounts up to 40-50% of the diet without problems. Above 50%, however, the animals intake of feed, and nitrogen retention (a measure of protein digestion and utilization) fell off quite rapidly. Thus with the present unselected wild kochia: "dilution is the solution". The recommendation to keep kochia hay to less than 50% of the ration is strongly in line with farmers experience.

- The best stage of maturity to cut kochia for hay was at late bud or early flower. This was the best compromise between yield, crude protein content, digestibility and reduced levels of nitrate and oxalate. Crimping the hay seems very important to hasten drying (e.g. use haybine type of equipment).

- In comparison trials on severely saline soils (EC = 10-20 mS cm^{-1}) kochia outyielded tall wheatgrass and slender wheatgrass by a factor of 2:1 to 3:1. The yield advantage of kochia was greatest where the salinity was highest*. Yields of kochia of 7 tonnes per hectare (3 tons per acre) on saline soils have been frequently obtained on research plots.

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*Studies on the mineral composition of kochia, and comparisons to tall wheatgrass and slender wheatgrass have been issued as a separate report. (Coxworth, Kernan, Crowle, Spurr, Green and Racz, 1987. Sask. Res. Council R-814-4-A-87).

ACKNOWLEDGEMENTS

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Additional support was provided by the Western Canada Kochia Association, Inc., and the South West Forage Association, in terms of assistance with demonstrations, providing contact with farmers growing kochia and in arranging meetings in various locations in southern Saskatchewan.

We thank the 54 farmers who took considerable time to provide information and general comments for the farm survey.

CHAPTER 1

FARMER TRIALS AND EXPERIENCE WITH KOCHIA

by

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BACKGROUND

Southern Saskatchewan has suffered serious drought conditions over a number of years during the 1980's. As a result of this, huge quantities of forage were trucked into this area at high cost in order that livestock producers could maintain their basic cow herds. At the same time many farmers with smaller cow-calf operations chose to liquidate their entire herds, thereby greatly reducing the cattle population.

Continuing seasons of drought further increased the acreage of salinity which farmers had been battling without much success.

It became evident through contact with farmers that some livestock producers had turned to harvesting and feeding wild kochia to their wintering cow herds. This kochia was growing naturally on saline acreage on their farms which would no longer produce other than a marginal crop of cereal. The success of feeding kochia, as a portion of the forage ration, harvested from what might be considered waste land, prompted investigation of this plant as a possible forage source to Southern Saskatchewan, utilizing otherwise saline acreage.

A total of 54 farmers in Southern Saskatchewan were interviewed, most in person, some by telephone, during the summer of 1987.

The following pages report some of the findings and information which farmers are relating regarding kochia:

GROWING AND HARVESTING WILD STANDS

- In nearly 100% of cases, kochia is growing as a volunteer crop in cultivated and cereal seeded fields.

- Kochia is growing in low lying sections of the field, such as pot holes or basins that are saline.

- Kochia is not generally considered a serious problem in the balance of cultivated fields that are not saline. The Weyburn area in 1987 was an exception.

- In the saline areas where it grows, it starts growth late (usually hot weathering and after showers in June), and overtakes the cereal crop (usually wheat or barley) and represents 75-90% of crop stand by harvest.

- Where patches are small, kochia and cereal are swathed when the cereal crop is swathed, left till after harvest, and disposed of by baling, chopping, or foraged by cattle where stubble is grazed. Kochia at this stage is often too mature and does not make ideal feed, although cattle still eat it, especially if it is put through a mix mill or tub grinder.

- Many farmers are trying extended or continuous cropping on fields that have considerable salinity. They are cultivating these fields and seeding cereal (usually barley) along with commercial fertilizer. They consistently get a stand of healthy, vigorously growing kochia in the saline areas.

- Some farmers are harvesting these areas of kochia at an earlier stage (near to or shortly after flowering) when the stand is less stalky and closer to ideal for feeding purposes.

- It is an absolute must to put this through a crusher-crimper unit in order to get the swath to dry. Even with this treatment drying or curing may take 5-10 days.

FARMERS' EXPERIENCES FEEDING KOCHIA TO CATTLE

- The majority of farmers bale this kochia up into large round bales and feed it free choice in feeders, electric wire, or roll it out on the ground.

- Nearly all kochia is being fed along with cereal straw and often some grain during cold weather and after calving.

- Tame or slough hay is also a part of the ration. Kochia as a part of the ration fed varies from about 10% up to as high as 50%[1].

- Not a single farmer interviewed has had any livestock losses attributed to feeding kochia hay. They have not encountered any illness that they consider has arisen from feeding kochia.

- The bulk of use of kochia as a forage has been to wintering pregnant beef cows.

- No calving problems or weak calves have resulted where kochia has been fed. Rather strong, healthy calves have been the rule.

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[1] Feeding more than 50% kochia can lead to problems. See the section on feed trials (Chapter 7, page 51 ff.)

- Palatability is not a problem when kochia is harvested at an early stage; it is often preferred to other feed. The problem of intake is limited to kochia harvested in the mature, stalky stage and not processed prior to feeding.

- Farmers have some concern over the length of time needed to dry and cure swaths of kochia especially where it has been swathed and not crushed or crimped.

- A few farmers reported some spoilage (mold and heating) of kochia put up in large round bales when baled before well cured. This is not a widespread problem and sometimes seems related to where other weeds are present in the stand. Kochia they say tends to permit baling without spoilage sooner than alfalfa.

FARMERS HAVE OFFERED SOME OF THE FOLLOWING SUGGESTIONS:

1. They are positive and optimistic about kochia as a livestock forage.

2. They want more information and research that will give reassurance and legitimation to its' use as a livestock feed.

3. Because of slow curing they would like to see trials using forage preservatives incorporated when baling large round bales (one farmer is testing a preservative).

4. Research into kochia put up as silage: alone, and in combination with sweet clover and cereals.

5. What about viability of kochia seed to germinate after it has passed through digestive tract of livestock? Concern regarding spreading manure on cultivated fields.

6. There is need for research using kochia as a summer pasture - now some use being made through after harvest stubble grazing.

7. In areas where kochia is a widespread problem through out fields, e.g., 1987, and because kochia seed is high in protein, should there be research into collecting kochia seed, leaves, and chaff in a chaff wagon behind the combine and utilize it as a livestock feed?

FUTURE DIRECTIONS FOR FARMER TRIALS

1. For every farmer interviewed there were frequently three or four others in the same district using kochia. Some of these should be interviewed also, particularly seeking those who have made some innovation, e.g. using hay preservative techniques, or who have had problems with kochia, either solved or unsolved.

2. Any reported cases of problems with feeding kochia should be followed up by feed scientists and/or animal scientists. Results should be reported in newsletters and farm bulletins.

3. Almost all the farm results to date have been done with unselected, wild kochia, usually occurring as wild, not deliberately planted stands. Results using selected types, e.g. using Texas seed, should be followed closely to identify opportunities, improved techniques of growing harvesting, and feeding, and identifying problems.

4. Several improved techniques for growing kochia have developed out of the farm interview results and the research results, e.g. the important roles of soil disturbance and soil fertility. These results need to be followed up with further farm trials, as well as more research experiments, designed to confirm the initial findings.

5. Conduct farmer trials, and research experiments to provide information on farmer suggestions 2 - 7 listed on the previous page.

COMMENTS ABOUT FARMER TRIALS AND EXPERIENCES

The farmers interviewed all had at least two years experience harvesting and feeding kochia. Thus their experience represents over 100 observations on kochia. This is very important in the development of a new forage crop, particularly one where there have been reports of problems using kochia elsewhere, e.g. in New Mexico. Farmers in Saskatchewan were being cautious and rarely if ever feeding more than 50% kochia in the ration. Under these circumstances there do not seem to have been any significant problems using kochia.

In feeding trials at the Melfort Research Station of Agriculture Canada, and at the Animal and Poultry Science Department of the University of Saskatchewan, animal intakes of diets containing less than 40-50% kochia were normal. These results were from studies using both cattle and sheep. When diets containing more than 50% kochia were tried, intakes dropped off very rapidly to less than 50% of normal. This suggests that kochia, at least in the unselected wild strains being used now, should always be less than 50% of the diet.

The farmer results are very important in providing observations on continued use of kochia over several years on a large number of animals and through the whole pregnancy cycle of beef cows. As long as kochia was kept to less than 50% of the diet, farmers reported remarkably few problems. In two instances where farmers reported one year in which one or several cattle died, the circumstances were related to late fall grazing in cultivated fields, where cattle may have been eating little else but late season kochia. In another case investigated by the Feed Testing Laboratory of the University of Saskatchewan, (Racz, 1986) a farmer had given two calves bales of kochia hay to eat, but nothing else. Both calves died. The oxalate content of this hay was high enough that much of the calcium in the hay may have been tied up as insoluble calcium oxalate. A diet for the rest of the farmer's cattle herd was developed in which kochia hay was only a part (~20-25%) and in which the other ration ingredients provided adequate available calcium. The farmer did not report any further problems. Other factors, e.g. nitrate, may also have been involved in this case.

A number of the reports of kochia toxicity problems on farms and in research studies have come from New Mexico and Colorado (Kiesling et al., 1985; Dickie and Berryman, 1979). Two factors may have been present in those experiences which may have been different than the much more positive Saskatchewan farmer trial results:

1. The New Mexico and Colorado problems occurred when kochia was usually the sole, or main, ration ingredient, e.g. when cows were grazing solid stands of kochia. In Saskatchewan, kochia was almost always kept at less than 50% of the ration.

2. Wild lines of kochia from New Mexico and Texas may have a greater tendency to accumulate anti-nutritive factors than Saskatchewan wild lines. In some of our research trials (see page 47) Texas kochia tended to have higher amounts of nitrate than Saskatchewan kochia. Thus any breeding and selection studies in western Canada should include testing

for tendencies to accumulate possible toxins. Studies in New Mexico have developed lines that are lower in oxalate and alkaloid (Smith et al., 1986) than the wild New Mexico types from which they were selected. These new selections should be tested in Saskatchewan.

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CHAPTER 2

POTENTIAL ANTINUTRITIVE COMPONENTS OF KOCHIA: ALKALOIDS

by

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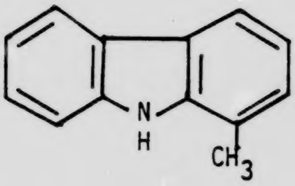
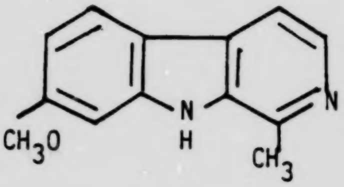
INTRODUCTION

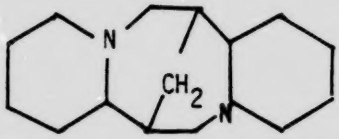
Serious problems with toxicity in kochia have been found in animal trials in New Mexico (Smith et al., 1986a, b; Karachi et al., 1986; Smith et al., 1985; Sosulski, 1987a; Green and Kernan, 1986). Following various isolation experiments, and small animal feeding trials, the New Mexico researchers concluded that the toxic agent was an alkaloid. Some evidence was obtained recently that the alkaloid present was sparteine (structure III below)(Bliss, 1987). A field method was developed to test for alkaloids in fresh leaves of kochia (adapted from Burns, 1964). This method was used to select for lines that were low in alkaloids, and other lines that were high. Rat feeding trials showed that the low alkaloid lines were considerably less toxic than the high alkaloid lines (Smith et al., 1986b).



Harmane (I)



Harmine (II)



Sparteine (III)

Polish studies (Drost-Karbowska et al., 1978) isolated very small amounts of harmane (I) and harmine (II) alkaloids from kochia. These alkaloids were not detected in the New Mexico studies, nor did the Polish studies detect the sparteine alkaloid found in New Mexico kochia.

To add to the complexity of the situation, farmers and researchers in Texas, quite close to an area in New Mexico which has had toxicity with kochia, have used kochia with few toxicity problems (Durham and Durham, 1979; Nieto, 1986). While some of the research feeding trial results have been of short duration (e.g. Sherrod, 1971, 1973), some farmers in Texas have fed kochia to cattle for a number of years without significant toxicity problems (Durham and Durham, 1979).

Because of the considerable uncertainty about toxic alkaloids in kochia, two actions were undertaken in the present study:

1. Interview 54 farmers to find out if toxicity problems were common in trials to use kochia as a feed in Saskatchewan.

2. Attempt to isolate alkaloids from Saskatchewan kochia.

RESULTS AND DISCUSSION

The background report gives details of the many methods to isolate and detect alkaloids which were used (Sosulski, 1987).

A colorimetric method for analyzing fresh leaves of kochia, using Dragendorff's reagent, was used to test for alkaloids. The color was not completely stable, and it was difficult to judge the intensity of the red-brown color produced on the test paper. Nonetheless, a strong color was produced with some samples of kochia. When tested with kochia with different levels of crude protein content, (fertilizer experiments), the color was strongest in kochia samples with the highest crude protein content, and which were grown with the highest rate of fertilizer.

Various methods of extracting alkaloids from dried samples of kochia hay were tested. Methods in which the kochia hay was treated with a base (i.e. made alkaline) before extracting with an organic solvent, gave some spectroscopic evidence (in the ultraviolet region of the spectrum) for harmane and harmine alkaloids. Attempts to verify the presence of these alkaloids by using thin-layer chromatography, or gas-liquid chromatography (GLC) were not successful. Although GLC analyses showed peaks at retention times where harmane and harmine would expect to be eluted, gas chromatography - mass spectroscopy revealed that the compounds eluted from the column at these retention times were not the suspected alkaloids.

More studies are required to settle the question of alkaloids in kochia. Since some initial evidence suggested the presence of harmane and harmine, considerable time was spent attempting to prove the presence of these alkaloids, without success. The methods used may not have been suitable for detecting sparteine. Some of the isolation methods should be repeated using detection methods more suitable to detecting sparteine.

If possible, seed from low alkaloid and high alkaloid lines of kochia developed in New Mexico should be obtained, and these lines grown in Saskatchewan. Feeding trials could determine if the low alkaloid line was superior to the Saskatchewan lines being selected.

A better method for quantitatively measuring alkaloids should be developed if possible.

From Chapter 1, there is little if any evidence for serious toxicity in local Saskatchewan kochia, fed as hay at less than 50% of the ration. It may be that the local wild types have naturally low levels of toxicity, including possible alkaloids. It may also be that the environmental conditions in Saskatchewan do not tend to favor the accumulation of alkaloids.

More research is necessary to determine whether alkaloids are present in Saskatchewan kochia, and whether alkaloids are, or could be, a potential problem here.

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CHAPTER 3

GRASSHOPPER RESISTANCE IN KOCHIA

by

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Current interest in kochia as a forage crop bought to light the observation made by farmers that it was not significantly damaged by grasshoppers even in areas severely affected by drought. The research project established in cooperation with SRC in 1986 and continued through 1987 was aimed at examining and quantifying this observation.

The results of this study showed that kochia was the least preferred plant to each of the four major pest species of grasshoppers. The dense stands of kochia in the study sites did not deter grasshoppers; thus ruling out shading as a deterrent factor. Despite the fact that grasshopper infestations were severe to very severe (up to 30 m^{-2}), feeding on kochia was very limited and grasshoppers actively avoided feeding on newly-formed leaves in favour of older leaves.

Grasshoppers were reared in the laboratory on kochia and their survival, growth and reproduction compared to others fed on Columbus wheat under the same conditions. When the first adults had appeared in the wheat-fed grasshoppers the number of each instar, on each of the diets was recorded. The results showed that development was substantially slower on kochia and much less synchronous as well. Development of kochia fed grasshoppers was even more attenuated by the time their first adults appeared, which is reflected in the mean time taken to reach adulthood. Seven-day old adults of kochia-fed grasshoppers were significantly lighter than those fed on wheat or oats, and survival to adulthood was also considerably lower among the kochia-fed grasshoppers (10% compared to 48% on wheat fed grasshoppers). Dissection of adult females at weekly intervals revealed that the rate of development of the ovaries was significantly lower in those fed on kochia. Slower growth, higher mortality and low ovariole weight all contribute to the low biotic potential, 0.14 compared to 1.4 on wheat, of grasshoppers fed on kochia.

Feeding studies strongly indicate the presence in kochia of substances with antifeedant properties towards grasshoppers. From among the known constituents of kochia, the alkaloids harmine were considered as contributing to this effect. When added to a standard test diet a measurable response was obtained only at concentrations of 2% and 4% dry weight, which are much higher than those recorded for kochia. In another test harmane and harmine solutions were dried onto lettuce disks and fed to grasshoppers. In this experiment much less of the treated disks were eaten than untreated lettuce disks, thus indicating the antifeedant effects of these compounds. The alkaloids may be concentrated in the growing tips of the plant, which would be consistent with observations of the distribution of alkaloids in other plants, and would explain the preference grasshoppers display for older leaves.

In summary, grasshoppers find kochia an attractive plant from a distance, they do not find it surface-repellant, but they are deterred from eating it, particularly the youngest leaves. When they do eat it in any quantity they suffer substantial reductions in survival, growth rate and reproductive capacity.

CHAPTER 4

POTENTIAL ANTINUTRITIVE COMPONENTS OF KOCHIA: OXALATE

by

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INTRODUCTION

Oxalate has been suspected of being a possible source of toxicity in kochia on various occasions (Kingsbury, 1964; Karachi et al., 1986). While other factors such as nitrates (Karachi et al., 1986) or alkaloids (Karachi et al., 1986) or saponins (Souto and Milano, 1966) have also been suggested as being factors in cases of toxicity in kochia, we considered that it was important to develop a rapid method of analyzing kochia samples for oxalate. We could then attempt to correlate oxalate content with methods of selecting, growing and harvesting kochia. This would help farmers and animal scientist to predict what conditions would likely cause high oxalate in kochia, and then to take appropriate precautions in feeding it (e.g. diluting with other ration ingredients, or adding feed supplements).

A near infrared reflectance (NIR) spectroscopy analytical method to measure soluble oxalate was developed in cooperation with the Feed Testing Laboratory and the Animal and Poultry Science Department of the University of Saskatchewan on another contract funded by the Canada - Saskatchewan ERDA agreement on agriculture. Results of that study are reported elsewhere (Kernan, 1987). In the kochia study, we used this NIR technique to analyze many samples of kochia for oxalate content. Some of these results are given elsewhere in this report in relationship to the feed value of kochia grown under various conditions.

In this chapter we report on the changes in oxalate content depending on types of kochia and growing conditions, and on a general conclusion concerning oxalate content and feed value of kochia.

RESULTS AND CONCLUSIONS

The results on the oxalate content of kochia compared to its' feed value, over a range of types and conditions, are shown in Table 1.

Table 1. Soluble oxalate content and feed value of kochia forage.feed

Sample and growing conditions[1]		Oxalate	CP[2]	Ash	IVOMD[3]
		% of DM			
Pot trial using calcium nitrate fertilizer					
	0 ppm N	0.7	8.5	11.1	50.2
	50 ppm N	1.8	8.9	10.8	52.4
	100 ppm N	2.4	13.5	13.2	57.0
	150 ppm N	3.5	17.6	14.5	57.8
Pot trial comparing three fertilizers					
	200 ppm manure N	1.1	8.8	11.9	52.7
	100 ppm urea N	2.5	12.9	13.1	56.4
	100 ppm nitrate N	2.8	13.6	13.2	57.6
Sauder farm samples					
	yellow stunted plants	2.2	8.7	13.1	55.5
	green vigorous plants	4.7	19.9	15.0	58.6
Variety trials at Swift Current					
	Selection 1	2.5	11.9	11.4	50.2
	Selection 2	3.4	13.5	11.2	51.4
	Selection 3	2.8	12.1	11.0	49.6
Fertilizer field trial Swift Current					
	0 kgN ha^{-1}	1.7	7.5	10.9	52.3
	56 kgN ha^{-1}	1.7	8.3	11.1	51.9
	112 kgN ha^{-1}	2.2	10.2	11.8	52.7
Co-op site at Saskatoon					
	Early cut	3.7	17.8	16.1	55.6
	Late cut	4.4	18.3	14.9	54.7

[1] 1987 harvest, local, unselected Sask. plants unless otherwise indicated.
[2] Crude protein.
[3] In vitro organic matter digestibility.

continued ....

Texas and Saskatchewan kochia				
Grown at Swift Current				
Texas, early cut	2.5	12.6	12.2	51.8
Sask., early cut	2.2	11.1	11.2	50.9
Texas, late cut	1.8	7.5	9.4	45.8
Sask., late cut	2.8	8.4	9.8	47.5
Grown at Vegas, Texas				
Texas selection	5.4	22.6	14.7	58.7
Sask. selection	5.1	18.7	13.1	53.7

There was a strong correlation between soluble oxalate content and protein content, which is shown graphically in Figure 1.

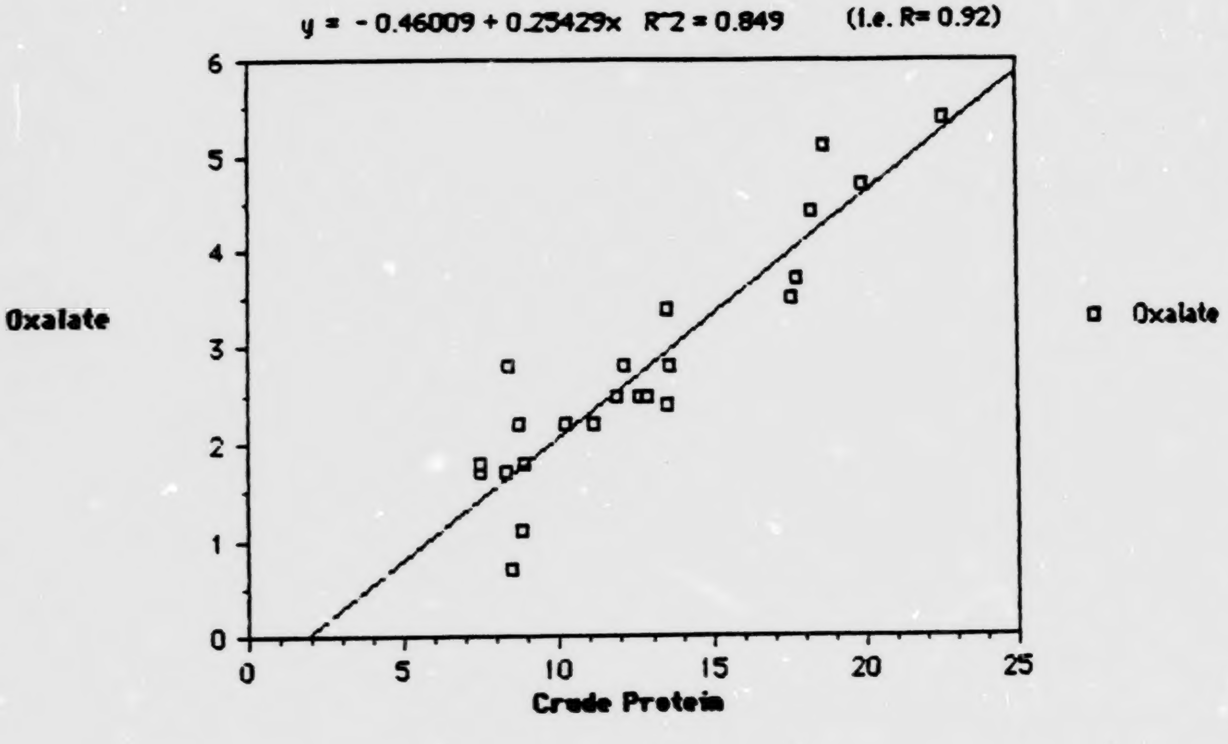

Figure 1. Relationship between oxalate and protein content of 1987 kochia samples.

We believe that kochia with over 15% protein would be used more as a protein source, and less as an energy source. Under these conditions the percent of kochia in the diet would go down as protein content in kochia went up. This would automatically reduce the oxalate content in the diet. Farmers should be strongly encouraged to have kochia samples, which are sent in to feed testing laboratories, tested for soluble oxalate content. This information would enable animal nutritionists to recommend rations which would contain adequate available calcium to counteract the negative effects of oxalate in the kochia component of the ration.

The levels of soluble oxalate found so far in Saskatchewan grown kochia are lower than some of the highest levels found in kochia grown in Texas and New Mexico, where values up to 9% have been found (Fuehring, 1982). How serious the highest of the Saskatchewan values is (e.g. 4.7%) would be dependent on what percent of kochia was used in the diet and whether feed supplements, such as the calcium hydrogen phosphate, (recommended for use in Texas (Fuehring, 1982)) were used.

The low incidence of reports of toxicity found in the 54 farmer survey in Saskatchewan suggests that by keeping kochia at less than 50% of the diet, most farmers seemed to be avoiding feeding problems which might be attributed to oxalate toxicity. Kingsbury (1964) stated that up to 0.2% of the animal's weight of soluble oxalate could be ingested without effect if taken in small amounts over a period of a day.

Plant breeders in New Mexico have had some success in selecting for low oxalate and low alkaloid content kochia plants (Fuehring and Finkner, 1984). These kochia selections should be tested for their productivity under Saskatchewan conditions, including saline soil situations. Feed value and concentration of these antinutritive constituents should be compared with local plant selections. Plant cell tissue culture techniques are available for selecting for low oxalate content of other plant species (Teutonico and Knorr, 1985) and may be of interest to test on kochia .

One conclusion from this present study is that methods to increase the feed value of kochia, e.g. using nitrogen fertilizer to increase protein content and digestibility, also tend to increase oxalate content (Table 1). Lush green vigorously growing kochia tends to have more oxalate than yellow stunted plants (Sauder farm, Table 1). This appearance may be a useful signal to farmers that such lush green kochia should be diluted with other ration ingredients to avoid oxalate toxicity problems.

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CHAPTER 5

FARM TRIAL OF THE EFFECTS OF SOIL CULTIVATION AND FERTILIZER ON THE YIELD AND FEED VALUE OF KOCHIA FORAGE

by

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INTRODUCTION

Wild stands of kochia in Saskatchewan often showed a marked reduction in height and yield in the second and third year of growth on the same site. This reduction in yield was accompanied by a large increase in plant density. Studies on wild kochia plant colonization of reclaimed surface mined soils in North Dakota showed this dramatic collapse of kochia yield (Iverson and Wali, 1981) (Table 1).

Table 1. Frequency, biomass yield, density and height of Kochia plants during the first three years of colonization of disturbed reclaimed soils (Iverson and Wali, 1981).

Years after Mining	Frequency %	Biomass $g\ m^{-2}$	Density plants m^{-2}	Height cm
1	100	222.5	52	53.7
2	98	70.8	10464	11.3
3	10	0.01	5	0.2

A field experiment by Iverson and Wali showed that when kochia plants in year 2 (density > 10,000 plants m^{-2}, or 930 plants ft^{-2}) were thinned down to approximately the density of first year areas (about 50 plants m^{-2}, or about 5 plants ft^{-2}), growth of kochia plants did not differ significantly by the end of the year. This provided strong evidence for phytotoxins (allelochemicals) produced in the first year of kochia growth which poisoned the soil for next year's kochia plants. Growth chamber experiments by Iverson and Wali showed that decaying kochia leaves and roots inhibited kochia growth but not the growth of wheatgrass or white sweetclover.

If kochia is to be deliberately grown on the same site several years in a row, this problem has to be overcome. Comments from farmers surveyed, as well as our own observations, suggested that soil disturbance could be a key factor in successful kochia forage production following kochia in the rotation. Soil fertility could also be an important factor in continued kochia forage production on the same site. Kochia forage production can remove large amounts of soil nitrogen, e.g., an 8 tonne per hectare (3.6 ton per acre) kochia crop containing 12.5% protein (or 2% nitrogen) removes 160 kg of nitrogen ha^{-1}, or 143 lbs nitrogen $acre^{-1}$. If manure is not recycled to these kochia forage production sites, there could be a major loss of soil nutrients, seriously limiting following crop yields. Second year stunted, overcrowded kochia stands often appeared yellow-green in colour, suggesting nitrogen deficiency.

A field trial was established to test the effects of soil disturbance (plant thinning), fertilizer application, and their interaction, on the yield of kochia forage on a site where kochia had grown and been harvested the year before. The field trial was planned and conducted by one of us (J.H.) with the active participation of the farmer, Mr. Keith Brownlee, Briercrest, Saskatchewan.

MATERIALS AND METHODS

The trial was established on the farm of Mr. Keith Brownlee, approximately 17 km (10 miles) west of Briercrest, Saskatchewan, south and east of the City of Moose Jaw. The site was a large saline soil flat several km north of the Cactus Hills. This area was cultivated and harrowed in the spring of 1986 and seeded to kochia by broadcast and harrowing. A variable stand of kochia emerged in 1986 and was harvested for feed. Sweetclover was broadcast in spring 1986 and had made a thin established stand for 1987. Growth represented the sparse stand of sweetclover along with a volunteer stand of kochia. Kochia growth varied from 2-4 inches in height and had a pale yellow green colour indicating unthrifty growth.

Variables studied in this field trial are shown in Figure 1, and were as follows:

1. Spring cultivation (Site 1) vs. no spring cultivation (Site 2).

2. Thinning of plants (soil disturbance) in mid June to reduce the kochia plant density vs. no thinning (two strips across treatments in item 1).

3. Two rates of nitrogen fertilizer, alone and with two rates of phosphorus fertilizer were implemented as test strips across the treatments described in variables 1 and 2.

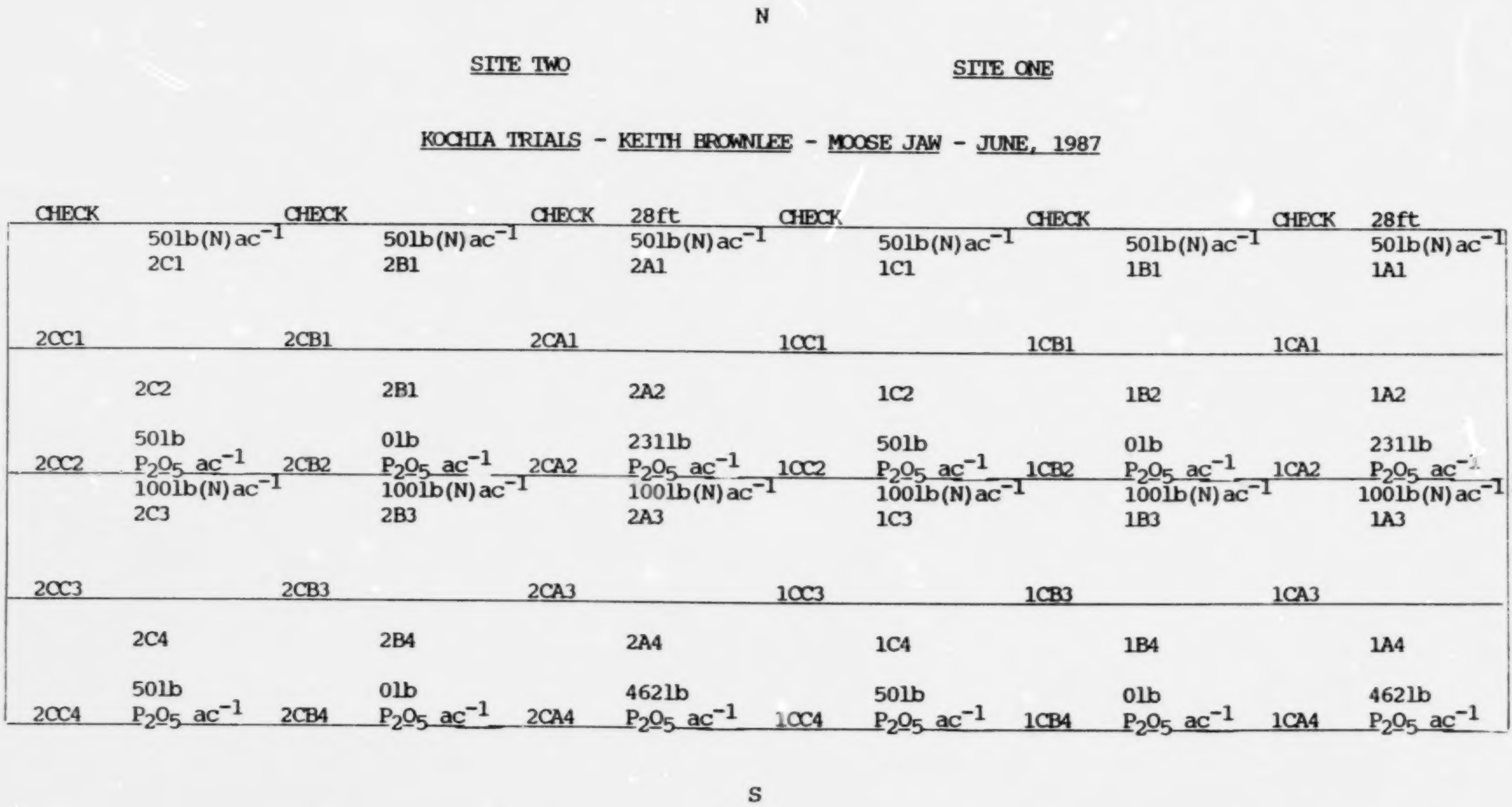

Figure 1. Design of field trials on the Brownlee farm to test the effects of spring cultivation, June thinning of plants, and type and amount of fertilizer on the yield and feed quality of kochia.

The history of plots one and two and the treatments applied to them were as follows:

Site One

This site was disced and harrowed in the spring of 1987 but not seeded. A somewhat patchy stand of kochia emerged which appeared to be growing normally and had the normal green colour. Approximately 0.80 inches of rain fell on the project area on June 16 making cultivation possible on June 19 without causing a severe lumping condition. This operation consisted of a single pass across and back (28 ft) using a 14 ft heavy duty cultivator fitted with 4" shovels on 12" spacing with flexible harrows attached behind. The surface on the cultivated portion after working tended to be slightly ridged due to action of the shovels and displacement of the kochia material.

For the major portion of site one, the cover of volunteer kochia was complete with quite a dense stand established. A plant count in the uncultivated plot gave an approximate number of 164 plants per square foot (1760 plants per square meter). In the area that had been cultivated, the count was 34 plants ft^{-2} (370 plants m^{-2}).

The nitrogen portion of the fertilizer was standardized at 50 and 100 lbs N ac^{-1} using different formulations of fertilizer. Thus, at 50 and 100 lbs N ac^{-1}, 27-27-0 applied 50 and 100 lbs P_2O_5 ac^{-1} respectively, 34-0-0 applied 0 P_2O_5 ac^{-1}, and 11-51-0 applied 231 and 462 lbs P_2O_5 ac^{-1} respectively.

Fertilizer was surface broadcast with a rear mounted spin type spreader which spread about 28 ft. It was applied across the cultivated and uncultivated kochia stands with a check plot adjacent to each of the fertilizer treatments. This produced 24 plots, each 28 ft square.

Site Two

Site two was immediately adjacent to site one but was not disced and harrowed in the spring of 1987. This site was cultivated and fertilized in the same manner and at the same time as Site one. Plant population count in the uncultivated plots were approximately 223 plants ft^{-2} (2400 plants m^{-2}) as compared to approximately 46 plants ft^{-2} (500 plants m^{-2}) in the cultivated plots. Substantial variation in plant density existed throughout this site.

Due to previous crop residue higher plant count, and lack of spring cultivation in 1987, the ridging and plant residue bunching was more evident here than in the cultivated portions of Site one.

The plots were harvested in the first week in August, when the plants were in full bloom. The sweetclover had been eliminated from site one by spring cultivation. On Site two, plants were separated into kochia and sweetclover by hand.

RESULTS AND DISCUSSION

Visual observation of this field trial on the 28th of July gave a number of clear differences. Site one, where spring cultivation was done, contained kochia plants which were taller and more vigorous than the kochia plants on Site two. Fertilizer gave a substantial yield increase as evidenced by taller and darker green plants. Less evident was the effect of June thinning (soil disturbance) of plants on yield and height on Site one.

Conclusions Treatment site one	Visual inspection Response
Spring cultivation	+ ve
Fertilizer	+ ve
Cultivation x fertilizer	+ ve
June thinning	little effect

Kochia growth on site two was much poorer than on Site one. June thinning caused a modest yield increase. Fertilizer gave a modest increase in yield, and the June thinning x fertilizer interaction appeared to be positive.

The most dramatic yield increase effects were seen for the spring cultivation x fertilizer interaction.

A considerable amount of kochia growth was observed by Keith Brownlee between our inspection of the plants on July 28 and when the plants were harvested in the first week of August. Unfortunately the way the demonstration was set up only included replication of the controls. However, assuming that the phosphorus did not have any effect, replication of the other variables can be obtained (Table 2). The spring cultivation, plant thinning (soil disturbance), and fertilization all had positive, practical effects on the yield, crude protein, and oxalate content of kochia. The in vitro organic matter digestibility of kochia was not affected. Since oxalate content correlates well with the crude protein content the variables probably only affected it indirectly.

The results indicate that the best combination of spring cultivation, plant thinning (soil disturbance) and fertilizer for this land was to spring cultivate, to disturb the soil while thinning the plants and to apply fertilizer, in this instance 50 lb N ac^{-1}.

Table 2. Effect of spring cultivation, soil disturbance and N fertilization on the yield and composition of kochia grown near Moose Jaw in 1987 (Brownlee farm).

Treatment	Yield (g m^{-2})	CP	Ash	IVOMD %	Oxalate	Nitrate
SPRING CULTIVATED						
Disturbed						
Cont A	850^{defg}	8.7^{abc}	10.6^{bc}	50.9	1.4^{a}	3 neg
50lb N	1665^{i}	11.9^{ef}	12.4^{f}	52.0	1.7^{b}	2 neg (1.3)
Cont B	775^{cde}	8.2^{ab}	10.6^{bc}	52.9	1.2^{a}	3 neg
100lb N	1184^{h}	12.6^{fg}	12.1^{ef}	52.2	2.0^{bc}	1 neg (trace)
Undisturbed						
Cont A	836^{defg}	8.1^{a}	11.0^{cd}	53.8	1.2^{a}	3 neg
50lb N	856^{defg}	9.2^{abc}	10.8^{bc}	52.3	1.3^{a}	3 neg
Cont B	645^{abc}	9.4^{bc}	11.0^{cd}	53.6	2.0^{bc}	3 neg
100lb N	965^{g}	12.0^{ef}	11.9^{ef}	51.6	1.9^{bc}	3 trace
NOT SPRING CULTIVATED						
Disturbed						
Cont A	703^{bcd}	9.3^{abc}	10.5^{bc}	53.2	2.1^{cd}	3 neg
50lb N	794^{cdef}	11.1^{de}	11.8^{ef}	54.5	2.1^{cd}	3 neg
Cont B	660^{abc}	9.6^{c}	10.8^{bc}	52.2	2.0^{bc}	3 neg
100lb N	844^{defg}	13.5^{g}	11.9^{ef}	54.7	2.9^{f}	2 neg (trace)
Undisturbed						
Cont A	570^{ab}	10.0^{cd}	10.2^{ab}	52.9	2.5^{de}	3 neg
50lb N	872^{efg}	12.5^{fg}	11.7^{e}	53.9	2.6^{e}	3 neg
Cont B	518^{a}	9.0^{abc}	9.9^{a}	52.1	2.3^{cde}	3 neg
100lb N	949^{fg}	11.6^{ef}	11.5^{de}	53.0	2.5^{dc}	2 neg (trace)
Sig. of treatment effect	**	**	*	NS	**	

Columns containing the same letter in the superscript are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

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CHAPTER 6

POTENTIAL ANTINUTRITIVE COMPONENTS OF KOCHIA: NITRATE

by

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INTRODUCTION

Kochia has been shown by previous researchers to sometimes accumulate toxic levels of nitrate (Kingsbury, 1984). Sublethal nitrate poisoning, in general, has been attributed to ingestion of feed containing between 1.5 and 0.5% of the diet. Levels above 1.5% may be fatal (Kingsbury, 1964). Studies with ruminant animals have shown that 0.05% of an animal's weight is close to the minimum lethal dose. With this potential problem, we considered it important to test as many kochia samples as possible for nitrate, and attempt to determine what factors tended to favor nitrate accumulation in kochia.

Samples were screened by the Feed Testing Laboratory for the presence of nitrate. Those that showed more than a trace of nitrate by the colorimetric screening test, were analyzed quantitatively for nitrate.

RESULTS AND CONCLUSIONS

Two hundred and six samples from various locations, and from various experiments, were analyzed. We tested for any correlation between crude protein and nitrate content but found no trends. With one exception, samples which tested over 3% nitrate contained over 20% crude protein. However, the majority of samples contained less than 0.5% nitrate, and 77% contained only traces, or less, of nitrate (Table 1).

Table 1. Number of samples containing various percentages of nitrate.

Percent of nitrate	Number of samples	Percent of samples
Zero or trace(0.01)	158	76.7
0.01 - 0.50	13	6.3
0.51 - 1.00	14	6.8
1.01 - 1.50	12	5.8
1.51 - 2.00	4	1.9
2.01 - 5.78	5	2.4

The stage of maturity of kochia had an effect on the amount of nitrate. Young plants had more nitrate than old (Table 2). In this experiment, delaying harvest until the end of July would have substantially reduced nitrate but still yielded forage of reasonable protein content (12.9%).

Table 2. Effect of the stage of maturity on the yield, crude protein nitrate, and oxalate content of kochia forage grown on a saline site at Swift Current in 1985.

Date harvested	Stage of maturity	Yield $t\ ha^{-1}$	Nitrate	Oxalate	Crude protein
			- - - - - - - - - - % of DM	- - - - - - - - - -	
July 7	Prebud	4.38	0.37	3.6	15.7
July 15	Bud	6.10	0.40	3.9	16.1
July 31	Early Flower	6.63	0.08	3.3	12.9
Aug. 16	Late Flower	7.16	trace	1.9	10.4
Oct. 1	Mature Seed	6.12	0.14	1.5	8.0

Increasing the nitrogen fertilizer level tended to increase the nitrate level, while also increasing crude protein (Table 3). However, the levels of nitrate reached, even with the highest rate of nitrogen fertilizer, was not considered serious in these experiments.

Table 3. Effect of nitrogen fertilizer level on nitrate and crude protein content of kochia (various experiments).

Experiment	Nitrogen fertilizer level	Nitrate	Crude protein
		- - - - -% of DM	- - - - -
Pot Experiment 1987, Saskatoon	0 g pot^{-1}	Negative	8.5
	9.2 g pot^{-1}	Negative	8.9
	18.4 g pot^{-1}	Negative	13.5
	27.6 g pot^{-1}	Trace	17.6
Saline gradient Swift Current, 1986	0 kg N ha^{-1}	Negative	10.4
	56 kg N ha^{-1}	Negative	13.5
	112 kg N ha^{-1}	0.12	16.0
Saline gradient Swift Current, 1987	0 kg N ha^{-1}	Negative	7.5
	56 kg N ha^{-1}	Negative	8.3
	112 kg N ha^{-1}	Negative	10.2

Comparison of Texas and Saskatchewan kochia in various experiments showed that Texas kochia had a greater tendency to accumulate nitrate in 1986 but showed no difference in 1987 (Table 4). Texas kochia had dangerous levels of nitrate in 1986. Similar tendencies of Texas kochia to have high levels of nitrate, especially with high available soil nitrate, have been noted in New Mexico (Karachi et al., 1988).

Table 4. Comparison of Texas and Saskatchewan lines of kochia for protein and nitrate content.

Experiment	Type of Kochia	Nitrate	Crude protein
		- - - - - % of DM	- - - - -
Swift Current Saline soil, 1987	Texas Sask.	Trace Trace	12.6 11.1
Vega, Texas 1987	Texas Sask.	Trace Trace	22.6 18.7
Rempel Site, Saline soil Swift Current, 1986	Texas Sask.	2.0 0.3	19.9 14.9
Brooks, Alberta Irrigated and Fertilized 1986	Texas Alberta[1]	2.5 1.0	18.3 14.9

[1] Wild stands of wild kochia growing close to the irrigated stand of Texas kochia.

In a number of instances, lack of soil disturbance in the spring, and possibly other effects such as low soil fertility, led to patches of dwarf, yellow to yellow-green leaved, densely crowded kochia plants.

These were frequently adjacent to nearby tall, green stands of kochia. Analyses of these plants showed that the tall green plants were always higher in both nitrate and protein (Table 5).

Table 5. Effect of plant size, color, and leafiness, on adjacent sites, on nitrate and crude protein content.

Site and	Appearance	Nitrate	Crude protein
		- - - - - - % of DM	- - - - - - -
Marin farm 1986	Tall, green Stunted, yellow	.5 Negative	13.5 6.7
Swift Current 1986	Tall, green, leafy Short, yellow	0.63 Negative	17.5 8.1
Swift Current 1986	Tall, green, lush Short, yellow	trace Negative	19.9 8.7

Abouguendia (1988) found a strong relationship between soil nitrate and kochia nitrate accumulation in leaves. Derdall (1988) grew Texas kochia under irrigation on a saline site very high in available soil nitrate (over 330 kg N ha^{-1}). Addition of phosphate fertilizer reduced plant nitrate substantially, although the level of nitrate was still very high (Table 6).

Table 6. Effect of phosphate fertilizer on the protein and nitrate content of Texas kochia grown under irrigation at Outlook, Sask. in 1987.

Treatment	Nitrate	Crude protein	Protein corrected for nitrate	TDN
	% of DM			
No phosphate	5.3	24.2	16.7	58-60
Phosphate added (48 kg P_2O_5 ha^{-1})	3.4	25.6	20.8	59-61

(Unreplicated farm trial)

Farmers growing kochia should be encouraged to have kochia hay or silage analyzed for nitrate, and take appropriate measures if some samples show high nitrate concentration.

Further growth room experiments are needed to test for growing conditions and genotypes of kochia which will tend to decrease, or increase, the level of nitrate accumulation. The effect of various ratios of soil N and P_2O_5 on nitrate accumulation in kochia should also be evaluated.

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CHAPTER 7

STUDIES ON THE VOLUNTARY INTAKE AND DIGESTIBILITY OF *KOCHIA SCOPARIA* HAY FED AT VARIOUS LEVELS WITH GRASS TO STEERS

by

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ABSTRACT

Three trials were conducted to evaluate the effect on intake and digestibility of adding Kochia scoparia hay to grass hay. In Trial I, 12 steers (4 per diet) were randomly allocated to: 100% hay (H), 100% kochia (K), or 100% K plus a calcium supplement of 2.64% $CaCO_3$ (K + Ca). In Trial II, 3 steers per diet were randomly allocated to one of 4 K:H diets (0, 20, 40, and 60% K). Trial III measured the effect on intake of gradual increases of K in the diet from 0 to 100% compared with a 0% kochia control. Three steers from the 0% diet in Trial II, were continued on the 100% H diet and three steers from the 20% K diet were given 40% K:60% H, gradually increased to 100% K. Salt and mineral supplements were supplied in Trial I to the H diet and to all diets in Trial II and III. Results for Trial I indicated no differences in dry matter intake per unit of metabolic body weight (DMI $kg^{-0.75}$) or organic matter digestibility (OMD) between K and K + Ca diets. Total nitrogen retained (TNR) and DMI $kg^{-0.75}$ for the two K rations were significantly lower than for H ($P<0.0001$). Potassium, zinc, iron and copper plasma levels were significantly elevated in the K rations vs H ($P<0.05$). In Trial II, TNR increased linearly as the levels of K decreased ($P<0.0001$). TNR in K:H diets 0 and 20% K was significantly higher than K:H diets at 40 and 60% K ($P<0.05$). There were no differences in OMD or DMI $kg^{-0.75}$ among the 4 diets. In Trial III, DMI $kg^{-0.75}$ decreased with gradual increases in dietary K levels ($P<0.001$). Results suggest that K can be included in a forage diet up to a level of 40% without adverse effects on TNR or DMI $kg^{-0.75}$.

INTRODUCTION

Kochia (Kochia scoparia, L. Schrad) is a wild annual plant very common on disturbed saline soil in western Canada (Braidek et al., 1984). It is an alkali halophyte which tends to accumulate more minerals such as potassium, calcium, magnesium, and sulfate, than non-halophyte forage crops (Redman and Fedec, 1987; Green et al., 1986; Coxworth et al., 1988). There has been interest from time to time in turning this wild plant into a forage crop, usually during periods of drought, when its great drought resistance was apparent. In the 1940's Erickson and Moxon (1947) evaluated kochia as a hay or silage crop for South Dakota. Short term animal trials with sheep and cattle revealed that it had comparable feed value and palatability to various medium quality hays to which it was compared. Shortly thereafter, Bell et al. (1952) tested kochia as a dryland hay crop for Saskatchewan. Yields were considerably higher (at up to 11 tonnes ha^{-1}) than other forages such as sweetclover, alfalfa, and oats. Protein content, depending on the stage of maturity at which the kochia was harvested, was almost as high as alfalfa. However, its ash content was higher than non-halophyte forages; furthermore, the intake of forage was not the highest of the various hays compared. Thus the intake of digestible energy was less than that of the common, non-halophyte forages.

In the 1970's, in northwestern Texas, Sherrod and his associates investigated the feed value of wild kochia fed as hay or silage to cattle or sheep (Sherrod, 1971, 1973; Finley and Sherrod, 1971). As the kochia matured, the proportion of hard, woody stems increased, and the amount of stems refused by the animals increased. The best compromise between yield and feed quality was at the early flowering stage of plant development. Combinations of kochia hay and alfalfa hay had the best feed intake and had much better nitrogen retention than kochia alone provided that the hay mixture contained at least 50% alfalfa. The rather high nitrate content of kochia hay (0.7%) was considered a possible factor in the poorer nitrogen retention of kochia hay compared to alfalfa hay, or mixtures of alfalfa and kochia (Sherrod, 1973).

More recent studies in Texas, New Mexico and Colorado revealed both opportunities for, and problems with the use of kochia by ruminant animals. Use of kochia as an annual pasture for cattle in Texas was reported to give high stocking rates and good animal performance (cows and calves) (Durham and Durham, 1979). These farm trials have continued with good results over a 9 - 10 year period (Durham, 1986). Since kochia can accumulate significant amounts of soluble oxalate, it was recommended to supplement the diet with dicalcium phosphate to counteract possible toxic effects. In contrast, serious toxicity problems occurred in New Mexico (Karachi et al., 1986; Smith et al., 1986; Kiesling et al., 1985) and in Colorado (Dickie and Berryman, 1979; Dickie and James, 1983). These toxicity problems occurred when animals grazed kochia pasture or were fed kochia hay. Photoencephalomalacia and photosensitization were common symptoms (Dickie and Berryman, 1979) and an alkaloid was suspected to be the main toxic factor (Smith et al., 1986). Selection for lower alkaloid content lines was successful, and these selected lines were less toxic when fed to rats (Fuehring and Finker, 1984).

None of the previously described research trials or farmer experiences were based on kochia grown on saline soils. It was considered desirable in the present study to assess the feed value of kochia grown on saline soil and fed to steers. The specific objectives of the study were:

(a) to compare kochia hay (with or without a calcium carbonate supplement) with grass hay when either hay was fed alone,

(b) to measure the effects of mixing kochia hay with 40, 60 or 80% grass hay,

(c) to measure the ability of steers to adapt to increasingly high proportions of kochia hay in the diet.

None of the new low alkaloid or low oxalate selections of kochia from New Mexico were available, so unselected wild kochia from Saskatchewan, was harvested for seed, and this seed sown on a saline soil site in the Radville area of Saskatchewan in 1986. The kochia was harvested at the early to midbloom stage of maturity in early August and was used for the three trials with steers.

RESULTS AND DISCUSSION

In Trial I, 12 steers (4 per diet) were randomly allocated to: 100% grass hay (H) (brome grass:crested wheatgrass mixture), 100% kochia (K), or 100% K plus a calcium supplement of 2.64% calcium carbonate (K + Ca). Salt and mineral supplements were supplied to the H diet but not to the K or K + Ca diets. The analyses of the diets and the digestibility, intake, and nitrogen retention of the three diets are shown in Table 1.

Supplementing the kochia diet with calcium carbonate (limestone) had no beneficial effects on feed value or feed intake. Feed intake and nitrogen retention were much poorer for both kochia diets (K or K + Ca) than the H diet. Potassium, zinc, iron, and copper plasma levels in the blood were significantly elevated in the kochia rations compared to the grass hay (H). Thus kochia hay was not an acceptable feed when fed alone.

In Trial II, 3 steers per diet were randomly allocated to one of four K:H diets (0, 20, 40, and 60% K). All diets were supplemented with salt and minerals. Mixing kochia hay with grass hay greatly improved intake (see Table 2) over the 100% K diets in Trial I. Total nitrogen retention was also improved on all mixed K:H diets compared to 100% K, with 20% K and 0% K diets being significantly better than 40% or 60% K diets (Table 2). Sherrod (1973) found a similar effect on nitrogen retention in mixtures of kochia and alfalfa hays fed to sheep. Nitrogen retention in diets of 0, 25 and 50% kochia were similar and much better (double) than those of diets with 75 or 100% kochia. Digestibilities

Table 1. Chemical composition and digestibility of 100% kochia (K), kochia plus calcium (K + Ca) and 100% hay (H) on a dry matter basis.

	DIET			CONTRAST	
ITEM	H	K	K+Ca	H vs (K & K+Ca)	K vs K+Ca
TRIAL I					
Dry matter %	93.8	94.3	94.3		
Crude protein %	12.8	9.10	9.10		
Ash %	9.6	11.1	11.1		
Nitrate %	trace	0.52	0.52		
Oxalate %	0.61	2.59	2.59		
MINERALS					
Calcium ppm	103.0	107.3	10667	NS	NS
Phosphorus ppm	72.4	89.8	87.9	*	NS
Magnesium ppm	23.3	27.4	25.2	NS	NS
Zinc ppm	1.08	1.26	1.28	*	NS
Iron ppm	1.80	2.60	3.36	*	NS
Copper ppm	0.80	0.95	1.04	*	NS
1 DMD %	59.95	57.62	57.17	NS	NS
2 OMD %	61.29	55.37	55.44	*	NS
3 TNR $g\ day^{-1}$	79.41	3.43	3.68	**	NS
4 DMI $kg^{-0.75}$	0.0878	0.0374	0.0230	**	NS

* Difference significant ($P<0.05$)
NS difference nonsignificant
** Difference significant ($P<0.0001$)
1 DMD, Dry Matter Digestibility
2 OMD, Organic Matter Digestibility
3 TNR, Total Nitrogen Retained
4 DMI $kg^{-0.75}$, Dry Matter Intake per Metabolic Weight

Table 2. Chemical composition and digestibility of kochia (K) and hay (H) fed at various set levels on a dry matter basis.

	DIET K:H				CONTRAST	
ITEM	60:40	40:60	20:80	0:100	LINEAR	QUADRATIC
TRIAL II						
Dry matter %	94.04	94.04	93.71	93.79		
Crude protein %	11.88	12.77	14.27	15.87		
Ash %	10.43	10.22	9.97	9.64		
Nitrate	trace	trace	trace	trace		
Oxalate %	0.61		0.73	0.65		
1 DMD %	54.81	51.75	51.37	51.96	NS	NS
2 OMD	53.59	51.13	50.77	51.80	NS	NS
3 TNR g day^{-1}	37.15	35.56	70.09	81.46	**	NS
4 DMI $kg^{-0.75}$	0.0766	0.0742	0.0881	0.0848	NS	NS

** Difference significant ($P<0.0001$)
NS difference nonsignificant
1 DMD, Dry Matter Digestibility
2 OMD, Organic Matter Digestibility
3 TNR, Total Nitrogen Retained
4 DMI $kg^{-0.75}$, Dry Matter Intake per Metabolic Weight

and intakes of the H diet and of the 60, 40 and 20% K diets in the present study (Trial II) were similar to each other in contrast to the results in Trial I.

Trial III measured the effect on intake of gradual increases of kochia in the diet from 40% to 100%. Six steers fed 0 or 20% K in Trial II were used in Trial III. Three steers from the 0% K treatment were continued on 100% H for the duration of Trial III. Three steers from the 20% K had the K content of their ration increased to 40 K:60 H for 7 days, then 60 K:40 H for 7 days and 80 K:20 H for 11 days and 100 K:0 H for 2 days. The 80 K:20 H ration was continued for 11 days because intake over the first 7 days flucuated considerably. The 100% K ration was discontinued after 2 days because of the very low intakes. All diets were supplemented with salt and minerals. The results shown in Table 3 reveal that the percentage of kochia can be increased in the diet up to 60%, but that beyond 60% K intake falls off very rapidly. Thus both Trials II and III indicated that 60% K is the upper limit to the amount of this kochia hay which would be acceptable in the mixed diet.

Table 3. Effect of gradual adjustment of kochia (K) on dry matter intake (DMI) adjusted to metabolic weight ($kg^{0.75}$) on a dry matter basis.

	DIET K:H					**CONTRAST**	
ITEM	0:100	40:60	60:40	80:20	100:0	LINEAR	QUADRATIC
TRIAL III							
1 DMI kg day^{-1}	6.770	6.240	5.973	3.810	1.387	*	**
2 DMI $kg^{-0.75}$	0.0867	0.0865	0.0829	0.0530	0.0193	*	**

* Difference significant ($P<0.001$)
** Difference significant ($P<0.0001$)
1 DMI kg day^{-1}, Dry Matter Intake in kg per day]
2 DMI $kg^{-0.75}$, Dry Matter Intake per Metabolic Weight

When the evidence from all three trials was assessed, they suggest that kochia hay can be included in a forage diet up to a level of 40% without adverse effects on dry matter intake or digestibility. Levels of kochia above 20% caused adverse effects on nitrogen retention. The reasons for this need further investigation. Sherrod (1973) did not find adverse effects on nitrogen retention until kochia exceeded 50% of the diet.

It should be stressed that these results, and all other results in the scientific literature and from farmer trials around the world, are based on wild kochia on which no plant breeding has been done to reduce levels of potential anti-nutritive components such as alkaloids or oxalates. The first selections for improved feed quality have been made recently in New Mexico (Fuehring and Finkner, 1984). These improved lines should be grown in Saskatchewan, and their feed value compared to the unselected Saskatchewan and Texas wild kochia accessions being used by farmers and researchers to date.

Results of a farmer survey conducted by Hansen in 1987 support the results found in this feeding trial. Farmers were feeding 10 to 50% kochia in the ration, mainly to pregnant beef cows. Some farmers observed that if the percent kochia in the ration exceeded 50%, feed intake decreased, animals started to lose weight, and there was sometimes diarrhea problems (Brownlee, 1988).

While this present study was underway, Mir et al. (1987) reported similar effects in studies feeding various levels of kochia hay with alfalfa to sheep. Dry matter intakes were similar at 0, 25 and 50% kochia (1018, 931, and 858 g day^{-1}, respectively) but fell off substantially when the kochia level reached 75% of the ration (652 g day^{-1}). Mir et al. concluded that kochia could be incorporated into high forage diets up to 50% of the diet without adverse effects on intake or digestibility.

In a trial with growing steers in New Mexico, Kiesling et al. (1986) found that feeding kochia alone to growing steers resulted in very poor rates of gain compared to alfalfa (Table 4). Mixing kochia 50:50 with concentrate greatly improved rates of gain, although still not equal to a 50:50 alfalfa:concentrate mixture. The net energy for metabolism of kochia was 83% of alfalfa, whereas the net energy for gain of kochia was only 57% of alfalfa (see Table 4).

Table 4. Effects of including kochia hay in diets for growing steers (Kiesling et al., 1986).

Diet for growing period	Rate of gain[1] (lbs day^{-1})	
	Growing	Growing plus finishing
Alfalfa only	1.74	2.38
Kochia only	0.28	2.08
Alfalfa 50% plus Concentrate 50%	3.12	2.70
Kochia 50% plus Concentrate 50%	2.39	2.70

56-day growing period followed by a 98-day finishing period. Finishing period diet was 85% concentrate plus 10% alfalfa and 5% cottonseed hulls (no kochia).

Calculated net energy for:

metabolism: alfalfa = 54, kochia = 45
gain : alfalfa = 28, kochia = 16

Mir et al. (1987) found that a 50:50 kochia:barley grain diet was consumed less readily than a 50:50 alfalfa:barley grain diet (1.9% of body weight compared to 2.4% of body weight).

A recent growing trial with steers in southern Alberta comparing kochia with alfalfa, indicated that the kochia was much inferior to the alfalfa (Riemer, 1987). The kochia used was produced from Texas origin seed material (not selected for low alkaloid or oxalate). Energy intake was poor when kochia was 50% of the diet. When the animals were taken off the kochia diet and placed on a finishing ration there was no compensatory gain, as there was in the trial in New Mexico conducted by Kiesling et al. (1986) (see Table 4). Riemer considered there was possibly some toxin present in the kochia which had affected the calves so they were not able to make up in gain on the finishing ration what they had lost in the growing period. Riemer concluded that kochia was not suitable as a component of diets for growing calves but might be acceptable as a percentage of a maintenance diet for pregnant beef cows.

GENERAL CONCLUSIONS

All of the evidence, including the results of the present study, suggest that kochia can best be used at levels not exceeding 40 - 50% of the diet. The results of other trials suggest that kochia (at least the present non-selected nor improved wild lines) should best be used as a component of the diet of pregnant beef cows rather than as part of the diet of growing steers. The results of the farm survey (Hanson, 1988) indicate this is how the great majority of farmers are successfully using kochia.

Kochia may be able to improve the stability of feed supply in drought years in southern Saskatchewan by virtue of its ability to utilize residual moisture in saline depressions. In such depressions the high salt content restricts the ability of conventional, non-halophyte forages to utilize the moisture remaining. In 1982, 1983 and 1986, average tame hay production in Saskatchewan was 2,692,000 tonnes (Agricultural Statistics, 1986). In the drier years of 1984 and 1985, average hay production was 2,132,000 tonnes, a drop of 560,000 tonnes. Based on available statistics, we have estimated that there might be 7,500 farms with cattle in the brown and dark brown soil zones, with an average of 67 beef cows per farm. If 2 tonnes of feed are needed per pregnant cow per winter feeding period, the total winter feed needs for cows would be 1,000,000 tonnes. If 75% of the decline in hay production in 1984 and 1985 occurred in the brown and dark brown soil zone, then the hay shortage in those areas would have been 420,000 tonnes (i.e. 42% of need).

In 1984 kochia yields on saline soils on two sites in Saskatchewan were two to three times those of tall wheatgrass and slender wheatgrass (Coxworth et al., 1988). Based on a kochia yield of 4 tonnes ha^{-1} on saline soil compared to 2 tonnes ha^{-1} of conventional forages, 210,000 hectares of land in kochia would be needed to meet the shortage. This represents 28 hectares (69 acres) per farm. Based on the farm survey (Hanson, 1988) the average area in kochia production per farm using kochia was about 20 acres. Farmers would need to arrange for purchase of kochia from one or more neighbors (who don't have cattle) to be able to meet their anticipated winter feed shortages. A number of farmers in Southern Saskatchewan are already doing this.

From this rough calculation, it would appear that kochia production might be of considerable value in meeting periodic shortages of feed for beef cows in Southern Saskatchewan. In more normal years, kochia use for feeding cows would free up larger amounts of more conventional forages, such as alfalfa, for feeding growing calves. New drought resistant annual legume hays, such as SEMU S1 peas (Biederbeck, 1988) may also be of use to improve feed supplies. While SEMU S1 peas, like kochia, are very resistant to grasshopper attack they are not reported to be saline tolerant. Their place would be in annual crop rotations on non-saline soils.

Further studies are warranted on selected lines of kochia with reduced levels of alkaloid and oxalate to determine if the use of these types of kochia would permit higher levels of kochia in the diet and/or better performance from growing animals.

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CHAPTER 8

THE EFFECT OF AMMONIATION ON THE FEED VALUE OF TALL WHEATGRASS COMPARED TO KOCHIA AT TWO STAGES OF MATURITY AND TO ALFALFA

by

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ABSTRACT

Soil salinity is a major problem in many regions of the Canadian prairies. Tall wheatgrass (TWG) and kochia are two species tolerant of saline conditions. Two trials were conducted to determine the feed value of these species compared to alfalfa. In the first trial, two maturity stages of kochia hay cut on either August 3 or August 29, and alfalfa hay cut at early bloom, were fed to sheep in individual metabolism crates. There was a significant decrease in the intake of digestible organic matter (DOMI) and digestible crude protein (DCPI) with increasing kochia maturity (31.6 vs 23.2 g DOMI $kg^{-0.75}$ (SE - 0.6; $P<0.05$) and 4.22 vs 1.41 g DCPI $kg^{-0.75}$ (SE - 0.001; $P<0.05$). The DOMI and DCPI for the alfalfa was 32.9 and 8.1 g $kg^{-0.75}$ respectively. In the second trial, ammoniated and untreated TWG was fed to sheep. Ammoniation increased the DOMI from 26.2 to 44.3 g $kg^{-0.75}$ (SE - 1.04; - $P<0.01$) and the DCPI from 1.39 to 5.97 g $kg^{-0.75}$ (SE - 0.21; $P<0.001$). A direct comparison between TWG and alfalfa or kochia cannot be made since the results came from two separate trials. However, ammoniated TWG and early cut kochia appear to be at least equivalent in feed energy value to alfalfa but lower in feed protein value.

INTRODUCTION

Tall wheatgrass (TWG, Agropyron elongatum (Host) Beauvois) and slender wheatgrass (SWG, Agropyron trachycaulum (Link) Malte var. typicum Fern.) are amongst the most saline tolerant perennial grasses recommended for use as hay in Saskatchewan (Guide to Farm Practice in Saskatchewan, 1987). We considered that both these forages would complement the potential use of kochia (Kochia scoparia L. Schrad), as high yielding forages for saline soils, eg:

Kochia - a high yielding annual, requires disturbed soil to grow well, not tolerant of flooding in the spring.

Slender wheatgrass - a short lived perennial, useful in short rotations, stands up to 5 weeks flooding in the spring.

Tall wheatgrass - a fairly long lived perennial, adapted to very saline soils that tend to be wet, also tolerant of flooding.

During discussions with animal scientists and farmers, it was noted that the palatability of these grasses was not as good as some other, less saline tolerant forages, although TWG is described by Walton (1983) as being a good quality, highly palatable hay. In our study of the yield and feed value of kochia, SWG, and TWG, we found that the in vitro organic matter digestibility (IVOMD) of SWG was significantly less than that of kochia or TWG (Coxworth et al., 1987).

One method known to improve the digestibility and palatability of poor quality grasses is ammoniation (Knapp et al., 1975). The ammoniation method appears to be restricted to poor quality hays and crop residues such as chaff and straw. With good quality hays there is the danger of creating toxic byproducts such as 4-methylimidazole, which can cause the nervous disorder called bovine bonkers, crazy calf syndrome etc. (Perdok and Leng, 1987). Gates et al. (1987) investigated the influence of thermo-ammoniation (ammonia plus heat in an enclosed oven) on the quality of warm-season grass hay for steers. Gates (1987a) did not observe any symptoms which would have indicated toxicity or hyperexcitability from any of the hays he used. Ammonia treated bermudagrass hay has been fed to growing heifers in their location in three separate winter trials without incident. Gibb and Baker (1987) investigated the performance of young steers offered silage or thermo-ammoniated perennial ryegrass with or without a fish-meal supplement. During the first two weeks of the experiment, they did observe several cases of hyperexcitability in animals receiving the treated hay diets. It therefore appeared to us that poor quality SWG or TWG might be improved in feed value by stack ammoniation (as contrasted with thermo-ammoniation in an oven) provided care was taken to avoid conditions (such as high temperatures) likely to cause formation of toxic byproducts.

We were unsuccessful in locating SWG hay for sale in Saskatchewan in two years of exploration. We were able to locate TWG in 1987, and this material was used in the ammoniation study reported herein.

The objective of the first study was to determine whether the feed value and intake of TWG could be improved by stack ammoniation, using ammonia treatment conditions in a plastic bag designed to improve crop residues while minimizing the risk of formation of toxic byproducts. The results of this study were compared to the results of an earlier study (Green et al., 1986) in which kochia hay, cut at two maturity stages, was compared to good quality alfalfa hay. The kochia hay was cut on August 3rd at full bloom, and compared with kochia cut on August 29th, at early green seed production. These stages represented the two main maturity stages which the farmer survey indicated were being used by farmers (see Chapter 1).

The details of the experimental conditions are given elsewhere (Cohen et al., 1988).

RESULTS AND DISCUSSION

Trial 1. - Effect of ammoniation on the feed value of TWG hay.

Ammoniation significantly increased the crude protein (CP) content and in vitro organic matter digestibility (IVOMD) of TWG (Table 1). CP was increased by 77% and IVOMD was increased by about 10 percentage units. These increases are similar to those observed with ammoniation of straw and chaff (Sundstol and Coxworth, 1986).

Table 1. The effect of ammoniation on the in vitro feed properties of tall wheatgrass.

	Kochia			Significance of ammoniation effect
		Ammoniated		
	Untreated	Lab.	Field	
CP (%)	8.6^a	17.0^c	15.2^b	**
Ash (%)	8.9^b	8.5^{ab}	8.3^a	**
IVOMD (%)	40.6^a	50.2^b	48.0^b	**

Means in the same row with the same letter in the superscript are not significantly different (P<0.05) according to Duncan's Multiple Range Test.

The ammoniation also increased the OM and CP digestibilities of TWG when measured in vivo in sheep (Table 2).

Table 2. Digestibility of tall wheatgrass organic matter and crude protein, before and after ammoniation.

Digestibility (%) of:	Tall wheatgrass		SE	Significance of ammoniation effect
	untreated	ammoniated		
Organic matter	59.2	65.9	0.71	**
Crude protein	49.6	61.6	0.84	NS

The increase in organic matter digestibility (OMD) by ammoniation was less when measured in vivo than in vitro, but the absolute values were much higher in vivo. The reason for these differences is unclear.

Ammoniation greatly increased intake of digestible nutrients (Table 3).

Table 3. Daily digestible nutrient intakes of untreated and ammoniated tall wheatgrass

Intake ($g\ kg^{-0.75}$)	Tall wheatgrass untreated	Tall wheatgrass ammoniated	SE	Significance of ammoniation effect
DOM	25.8	44.3	1.45	**
DCP	1.33	9.67	0.124	**

Trial 2. - Effect of stage of maturity on the feed value of kochia compared to the feed value of alfalfa.

The CP content of both cuts, particularly the second (Table 4), were below those reported by other workers. Bell et al. (1952) reported values of up to 21% for some Utah and South Dakota accessions of kochia. Sherrod (1971) reported CP content as high as 25% for early cut forage and 14% (Sherrod, 1973) for midbloom material. Finley and Sherrod (1971) showed the CP content decreasing from 24% at prebloom to 13.5% at full bloom. The low quality of the Swift Current samples was believed due to a combination of cutting both samples at too late a stage of maturity, and leaf loss due to baling under very dry conditions.

The digestible nutrient contents of kochia also decreased significantly with advancing maturity except for digestible acid detergent fibre (ADF) and digestible neutral detergent fibre (NDF, Table 5).

Table 4. Composition of kochia and alfalfa.

	Kochia (%)		Alfalfa (%)
	Full bloom	Early seed	Early bloom
CP	10.5	6.4	17.3
Ash	13.2	9.4	11.4
Cellulose	30.7	34.9	31.4
NDF	51.0	61.1	--
ADF	32.2	38.9	--
IVOMD	57.3	48.7	62.0

Table 5. Digestible nutrient content of alfalfa and kochia (in vivo).

Digestible content (%) of:	Kochia		SE	Significance of maturity effect	Alfalfa
	Full Bloom	Early seed			Early bloom
Organic matter	51.4	43.1	1.93	*	52.7
Crude protein	7.0	2.7	1.38	*	13.2
Cellulose	17.5	11.1	0.052	*	15.9
NDF	25.2	24.6	0.78	NS	--
ADF	11.6	13.6	0.69	NS	--
Energy[1]	10.12	8.40	0.194	*	10.29

[1] MJ kg^{-1}

The OMD and energy digestibility decreased significantly between the two cutting dates, while the CP digestibility decreased greatly (Table 6). The digestibility of cellulose also showed a large decrease as did that of NDF, while the ADF digestibility did not decrease significantly.

Table 6. Nutrient digestibilities in kochia at two stages of maturity.

Digestibility of (%)	Kochia Full bloom	Kochia Early seed	SE	Significance of maturity effect
Organic matter	61.7	50.5	1.98	*
Crude protein	61.1	36.7	3.43	**
Cellulose	57.8	36.5	0.84	**
NDF	52.6	42.4	2.01	*
ADF	42.2	37.3	1.89	NS
Energy	60.9	49.1	2.37	*

The intakes of digestible OM and CP in kochia decreased with advancing maturity (Table 7). The digestible energy intake decreased from 601 to 431 kJ kg$^{-0.75}$ as the plant material matured from August 3, 1984 to August 29, 1984. Energy intake requirements for maintenance range from about 502 to 543 kJ kg$^{-0.75}$. The August 3 material was adequate in both energy and protein and cows could gain weight on feed of this quality. The August 29 material was marginally adequate for energy, but would require supplemental protein for it to be adequate for a maintenance ration.

Early cut kochia appeared similar to alfalfa in intake of digestible OM, cellulose, and energy, but inferior in digestible CP intake. It should be borne in mind, however, that kochia lost some leaf material during baling.

Table 7. Daily digestible nutrient intakes of kochia and alfalfa.

Intake of (g kg$^{-0.75}$)	Kochia		SE	Significance of maturity effect	Alfalfa
	Full bloom	Early seed			early bloom
DOM	31.6	23.2	0.6	*	32.9
DCP	4.22	1.41	<0.001	*	8.1
D Cell	10.4	5.7	0.44	*	9.7
DNDF	15.0	12.6	0.30	*	--
DADF	7.0	7.0	<0.001	NS	--
DE[1]	601	431	24.1	*	629

[1] kJ kg$^{-0.75}$

It should be borne in mind that the previous chapter (Chapter 7) showed that intakes of kochia and animal performance were much better when kochia was fed at no more than 50% of the diet. The trial described in this chapter was designed to compare kochia at two stages of maturity. Other trials would be needed to assess the effects of stage of maturity of kochia when kochia was no more than 50% of the diet.

CONCLUSIONS

TWG, either untreated or ammoniated, cannot be directly compared to kochia or alfalfa since the results came from two separate trials. However, ammoniated TWG and early cut kochia appear to be equivalent to alfalfa in feed energy and feed energy intake, but lower than alfalfa in feed protein digestibility and intake.

Ammoniation substantially improved the feed value of the TWG hay. No attempt was made to determine whether ammoniation of TWG produced bovine bonker's toxins. In general, the poorer the quality of the hay, the less likelihood there is to produce ammoniation toxins. Longer term trials, and chemical analyses for imidazoles, would be required to determine if poor to medium quality TWG (or SWG) can be safely ammoniated to increase their feed value.

Combinations of ammoniated TWG hay with alfalfa, or of kochia hay with alfalfa should both be tested for possible positive interactions. Brandt and Klopfenstein, (1986) found that combinations of ammoniated corn cobs with 15-30% good quality alfalfa gave much better rates of gain in steers than would have been predicted on the basis of the feed value of either forage. Sherrod (1973) found that combinations of 1:1 kochia hay and alfalfa hay gave much better nitrogen retention in sheep, than when kochia was fed as the only protein source. The effect was non-linear, suggesting some sort of beneficial interaction of alfalfa with kochia protein or non-protein nitrogen.

It should also be borne in mind that particle size reduction (eg. hammermilling) is another method to improve intake of hays, particularly poor to medium quality materials. More studies would be required to assess the relative merits of these two alternative techniques to improve the feeding performance of animals fed TWG hay.

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CHAPTER 9

FARM TRIALS ON METHODS OF SEEDING KOCHIA TO OBTAIN A RELIABLE STAND OF ACCEPTABLE PLANT DENSITY

by

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INTRODUCTION

Most of the kochia used for feed in western Canada has been harvested from wild stands which were not deliberately planted, but self sown from wild plants in the area (see Chapter 1). However, as farmers and researchers begin the development of domestic varieties of kochia, with non-weedy character, and improved feed value, the need to learn how to deliberately plant kochia has become important. Kochia has a very small seed (about 1 gram per thousand seeds, about the size of sesame, and about one-third the size of canola seeds). Thus it has been found difficult to plant accurately, both with respect to depth and number of seeds per unit area, to get a good stand of kochia.

Kochia frequently occurred as wild plants in stands of barley on saline land (Chapter 1, and Hanson, 1988). Some farmers felt that mixed stands of kochia and barley produced forage of better quality than kochia alone.

This chapter describes how several farmers have succeeded in developing methods to successfully sow kochia either alone or in combination with other crops.

RESULTS AND DISCUSSION

Experiences in Texas

In 1986, Kernan and Green visited various farmers and researchers in Texas and New Mexico to learn of their results on growing and feeding kochia (Kernan 1986). All the Texas and New Mexico results are from non-saline soils.

Mr. Adam Nieto of Vega, Texas has had considerable experience growing kochia to use as annual pasture, for hay production, or for harvest of seed. Mr. Nieto seeded with a drill at a rate of about 3 lbs acre^{-1} (3.4 kg ha^{-1}). He worked the land first to prepare a seed bed. He taped over every other run in the seed box of the drill. The spouts were removed from the drill so that the seed fell directly from the seed box to the ground. The action of the discs was sufficient to cover the seed with about the right amount of soil. (Ray Derdall near Outlook, Sask., and Darald Marin near Radville, Sask., have also used similar methods).

Mr. Jim Walker, county agent near Vega, has worked with a number of farmers who have been growing kochia. He recommended sowing oats into volunteer kochia at about half the normal rate for oats. If there was sufficient rainfall, a good mixed stand of oats and kochia resulted. The act of sowing and growing oats tended to reduce the kochia population to a more desirable level.

Darald Marin Radville, Sask.

Most of Mr. Marin's experience has been on seeding kochia onto saline soil. The soil is worked in the spring as if in preparation for seeding barley. Any volunteer kochia is killed by spraying with 2,4-D - Banvel mix before seeding selected kochia. Kochia has been seeded by several methods. In one method an old seed drill was modified to seed kochia. Every other run was closed off, similar to the method used by Adam Nieto in Texas. A Barber spreader and a Valmar spreader were also used. If the Valmar spreader was set for double the Avidex rate (about 7 lbs ac^{-1}) it would seed kochia at 3-4 lbs ac^{-1}. Mr. Marin was being paid more by his neighbors for mixed kochia/barley hay (1/4 ¢ lb^{-1} more in the field for mixed hay). After seeding kochia by broadcasting, barley was seeded at the normal rate (60 lbs ac^{-1}) using a drill, a double discer, or a hoe drill (no harrows). The barley was fertilized with 50 lbs N ac^{-1} (deep band) and 20-25 lbs phosphate ac^{-1}. The act of seeding the barley covered the kochia seed adequately.

After several years of using this system on quite saline land he is now getting a good even stand of mixed kochia-barley.

After the crop is harvested for hay, Darald Marin worked the land in the fall and perhaps one time in the spring. The residue from the kochia roots and stubble seems to protect the cultivated land with adequate trash cover and he has not had problems with soil drifting.

As tame non-weedy kochia is developed, a future problem could be with contamination with wild stands of kochia in the neighborhood. Darald Marin strongly stressed the need to harvest all wild stands, e.g. road edges, for hay, so that seed from these sites does not contaminate planted, managed stands of domestic kochia in the future. This is also an important part of a management strategy to control wild kochia as a weed now.

Ray Derdall, Outlook, Sask.

In 1987 Ray Derdall obtained Texas kochia seed from Adam Nieto, Vega, Texas to test on a saline area on Mr. Derdall's farm near Outlook. The saline area was in a field which was irrigated. The saline site had grown a very poor crop of barley in 1986 probably because of the salinity. Texas kochia was chosen to seed since it has a very long growing period in Saskatchewan and rarely sets seed. Thus there was no problem in introducing a weed into the field.

The site was plowed to a depth of 4-6", allowed to dry out, and then double disced three times to break up lumps, kill weeds, and firm up the seed bed.

Several methods of sowing the seed were tried. Attempts to use a Spirco Granular Avidex Applicator did not work. The rate could not be adjusted to 3-4 lbs kochia seed per acre, and seed fell out of the seed box by vibration. A Massey Ferguson 620 press drill was tried but the seed cups could not be turned down enough to give the desired seeding rate.

A good method was to mount a grass seeder onto the rear of a Massey Ferguson press drill set with 6" spacings. The drop spouts from the grass seeder were located just to one side of the coulters. When seeding, the coulters were put into the ground and allowed to turn. As the coulters turned they threw a very fine blanket of dirt over the seed. Depth and rate of seeding (3-4 lbs ac^{-1}, or 3.4 - 4.5 kg ha^{-1}) were very acceptable. This method led to 42-45 plants ft^{-2} (480 -484 plants m^{-2}). With plenty of soil fertility and combined rainfall and irrigation, this plant density resulted in fine stemmed kochia considered to be of good feed quality.

This site had a very high soil nitrate, presumably because of the saline soil and little crop growth the previous year. Part of the field was deep banded with 11-51-0 to attempt to balance the N to P ratio. Comparison of the feed value of kochia grown with fertilizer, or not, showed that the use of phosphate fertilizer increased crude protein and decreased nitrate (Table 1).

Table 1. Effect of phosphate fertilizer on feed value of Texas kochia grown with irrigation on a saline site near Outlook, Sask., in 1987.

Sample	Crude Protein	Nitrate	Protein minus nitrate	TDN
	% of DM			
Unfertilized	24.2	5.3	16.7	58-60
Fertilized	25.6	3.4	20.8	59-61

Kochia sown and fertilized in this manner gave a yield of 4.95 tons/ac (11.1 tonnes ha^{-1}) (two cuts) which was considered a very good yield for this previously unproductive saline area. The high nitrate in the kochia may be the result of the extremely high soil nitrate in 1987 on this site.

Research Results

Kochia seed as harvested by the combine is enclosed in a papery, five-pointed calyx. There is a pericarp (outer layer) on the seed itself which is fairly easily removed by rubbing. Abouguendia (1988) found that removal of the calyx (by rubbing) increased the extent of germination of the seed, particularly when the seed was germinated in a saline environment. In a similar study we found (Coxworth et al., 1988) that removal of most of the pericarp gave more complete germination.

Kochia seed varies greatly in seed size. We found that large seed germinated more completely than small seed (Table 2).

Table 2. Percent germination comparison (in 48 hours) of two sources of kochia seed, four seed sizes, with or without pericarp.

Seed size based on mesh size	Texas (Nieto)		Saskatchewan (Marin)	
	Pericarp coated	Uncoated	Pericarp coated	Uncoated
>16	93	100*	69	97
>18	90	97	77	91
>20	81	93	60	77
>30	56	69	24	34

*Germination complete in 8 hours.

Furthermore, large seed could be planted deeper than small seed, and gave larger seedings after 21 days (Table 3).

Table 3. Effects of seed size and planting depth on fresh weight of kochia seedlings after 21 days.

Seeding depth (mm)	Seeding depth (inches)	Seed size	Fresh weight (g)
6	0.24	Small	2.15^b
10	0.39	Small	2.18^b
15	0.59	Small	1.58^a
6	0.24	Large	2.64^b
10	0.39	Large	3.21^c
15	0.59	Large	2.53^b

Means within a column with the same superscript are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Further studies are needed to determine if selection for large seed size will lead to a higher yield of forage.

CONCLUSIONS

Farmers have found several methods to plant kochia successfully. Since kochia has to be planted very shallowly, rain (or irrigation) is needed after planting to get the plants established. Removal of the calyx and pericarp from the seed helps to increase germination. Selection for large seed size allowed kochia to be planted deeper and gave larger seedlings. These results should be the basis for further research and farm trials.

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CHAPTER 10

STUDIES ON THE EFFECT OF FERTILIZER ON THE YIELD, NUTRITIVE VALUE AND TOXICITY OF KOCHIA SCOPARIA HAY

by

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A. THE EFFECT OF FORM AND CONCENTRATION OF FERTILIZER NITROGEN ON YIELD AND QUALITY OF KOCHIA GROWN OUTSIDE IN A POT STUDY

by

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ABSTRACT

This experiment consisted of two outdoor pot trials to investigate the effect of fertilizer types and levels on the germination, yield and composition of kochia. Both trials were conducted at a constant level (98 ppm) of P_2O_5 and at an adequate moisture level (70% field capacity).

Trial 1 compared four levels of nitrate-nitrogen (calcium nitrate), 11 (control- no added N), 54, 100 and 146 ppm. The highest level significantly ($P<0.05$) reduced the germination rate. The second lowest level significantly ($P<0.05$) increased above ground dry matter yield over that of the control. Crude protein, ash, in vitro organic matter digestibility and oxalate levels increased directly with an increase in nitrate-nitrogen fertilizer. A trace of nitrate was observed for kochia grown only at the highest level.

Trial 2 compared three different fertilizer types, manure, urea and calcium nitrate. Urea and calcium nitrate were added to the soil at the same nitrogen level as for level 3 in Trial 1. Manure was added at double this amount since it is a slow release type fertilizer. The kochia fertilized with manure was very similar in all respects to the

control from Trial 1. Kochia fertilized with urea and calcium nitrate gave results very similar to each other and to kochia from level 3 (100 ppm N) in Trial 1.

INTRODUCTION

Kochia (Kochia scoparia L. Shrad.) samples collected in the fall of 1986 from an area heavily fertilized with anhydrous ammonia did not contain nitrate. Other samples from areas which had been fertilized with nitrate fertilizer and manure contained large amounts of nitrate.

This trial was initiated in 1987 to investigate kochia's response to fertilizer in both yield and quality, and to determine if the form in which the fertilizer was applied would affect its' nitrate content.

MATERIALS AND METHODS

A similar procedure to that described by Lugg et al., (1983) was used to conduct a greenhouse trial in which the amount of nitrogen (N) and phosphorus (P) were varied to determine the effect on yield, quality and oxalate content. We used a 2:1 mixture of sandy loam and coarse sand (henceforth called soil) and added calcium nitrate, urea, triple super phosphate and Vigero cattle manure as sources of fertilizer.

Trial 1 was to determine the effect of different amounts of nitrate-nitrogen fertilizer on the dry matter (DM) yield and feed value [expressed as crude protein (CP), ash and in vitro organic matter digestibility (IVOMD)]. Also included were oxalate and nitrate, two potentially toxic components of kochia.

Sized kochia seed obtained from one plant harvested in October, 1986, was planted in plastic pots set into the ground to prevent overheating. Each pot contained 19.5 kg of soil, 3.6 g of triple super phosphate and calcium nitrate as described in Table 1. Four replicates were used per treatment. Initially 21 seeds were planted in each pot which were later reduced to seven healthy seedlings. Each pot was maintained at 70% field capacity by weighing a control pot daily.

Table 1. Nitrate fertilizer concentrations.

Treatment	$Ca(NO_3)_2.4H_2O$ added (g)	N added (g)	Conc. of added N (ppm)	DM Conc. of added N (ppm)	Conc. of added N (kg ha^{-1})*
1	0	0	0	0	0
2	9.2	1.1	46	48	180
3	18.4	2.2	92	97	360
4	27.6	3.3	137	145	540

*On the basis of the soil surface area, 607.2 cm^2.

All pots were harvested after 52 days growth. The kochia plants were air dried, hammermilled through a 1.25 cm screen, ground through a 1 mm screen in a Wiley mill, and through a Udy grinder when near infrared reflectance spectroscopy (NIRS) was required. Representative samples were submitted to the Feed Testing Laboratory (FTL), University of Saskatchewan for CP, ash, IVOMD and oxalate [by NIRS, Shenk et al., 1979] and nitrate analyses. Analyses were conducted at the FTL to provide the calibration base for CP [A.O.A.C., 1984 (N x 6.25)], ash (A.O.A.C., 1984a) and IVOMD [Troelsen, 1971 (adaption of the method of Tilley and Terry, 1963)]. Oxalate analyses for the NIRS calibration base were conducted at the Saskatchewan Research Council according to the procedure of Dye (1956). Spot tests to determine the presence of nitrate were a modification of the procedure of Hure and Ortis (1949). When qualitative calorimetric tests were positive, nitrate was quantified by a modification of the method of Hoffman and Lundell (1937).

Trial 2 was designed to determine if there was a difference between three forms of nitrogen fertilizer on the dry matter yield, feed value, oxalate, and nitrate contents of kochia. This experiment was conducted in the same manner as described for Trial 1 with the following exceptions. Since manure is a slow release nitrogen twice the theoretical amount of manure was added to the soil based on its nitrogen content, and it was completely mixed with the soil before water was added. Table 2 gives the amounts and concentrations of calcium nitrate, manure and urea incorporated into the soil.

Seeding and watering were conducted as described for the Trial 1. The plants were harvested after 51 days growth and processed and analyzed as described for Trial 1.

Table 2. Amounts and concentrations of $Ca(NO_3).4H_2O$, urea and composted cattle manure incorporated into the soil/sand mixture.

Treatment	$Ca(NO_3)_2.4H_2O$ added (g)	N added (g)	Conc. of added N (ppm)	DM Conc. of added N (ppm)	Conc. of added N (kg ha^{-1})*
Manure**	1023	4.4	183	193	720
Urea	4.7	2.2	92	97	360
$Ca(NO_3).4H_2O$	18.4	2.2	92	97	360

* On the basis of the soil surface area, 607.2 cm^2.
** Slow release nitrogen source - double amount added.

RESULTS AND DISCUSSION

For Trial 1, the germination percentage for the pots fertilized with the largest amount of calcium nitrate was the lowest (Table 3) and was significantly ($P<0.05$) lower than the germination percentage for the control pots and those fertilized with the smallest amount of calcium nitrate.

Table 3. The effect of calcium nitrate concentration in the soil on the kochia germination percentage.

Treatment	NO_3-N (ppm) ($Ca(NO_3)_2$ fertilizer) added	total	Germination (%)
1	0	11	67^{a}
2	46	54	60^{a}
3	92	100	52^{ab}
4	137	146	39^{b}
Significance of treatment means			*

Means in the same column with the same letter in the superscript are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

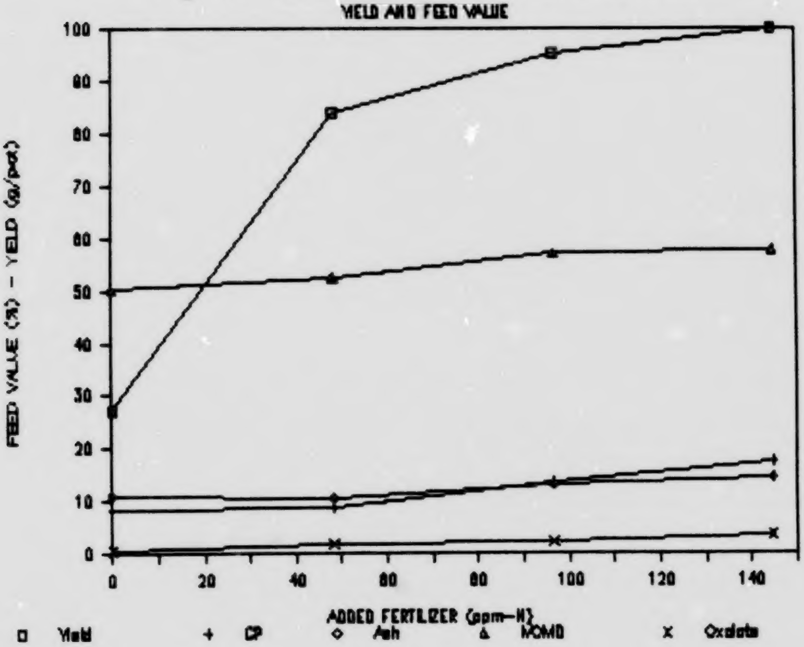
The yield of kochia varied directly with the amount of nitrate fertilizer added (Table 4, Figure 1). However, the only significant increase in yield was obtained following the addition of 9.2 g of hydrated calcium nitrate per pot, although further increases were achieved following the addition of larger amounts of fertilizer.

Table 4. The effect of added fertilizer ($Ca(NO_3)_2.4H_2O$) on the dry matter yield of kochia forage.

Added fertilizer (g pot^{-1})	Dry matter yield (g pot^{-1})
0	27^a
9.2	84^b
18.4	95^b
27.6	100^b
Significance of treatment effect	*

Means in the same column with the same letter in the superscript are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

Fig. 1. CALCIUM NITRATE ON KOCHIA



The nutritional value, oxalate, and nitrate contents of kochia forage also varied directly with the amount of fertilizer added (Table 5, Figure 1). The improvements in CP and IVOMD were not significant following the addition of 9.2 g of fertilizer per pot, the level which gave the only significant increase in yield (Table 4). Significant improvements in CP and IVOMD occurred following the addition of 18.4 g and 27.6 g of fertilizer per pot. The ash content also increased directly with the amount of fertilizer added, probably due to an increased leaf to stem ratio. In other words, the first increment of N fertilizer increases yield, but has little affect on feed values; further increments of N fertilizer increase feed value (CP and IVOMD) but have lesser effects on yield.

Table 5. Effect of added fertilizer ($Ca(NO_3)_2.4H_2O$) on some nutritional and toxic components of kochia forage.

Fertilizer (g pot^{-1})	CP	Ash	IVOMD	Oxalate	Nitrate
	- - - - - - - - - - - - % of DM - - - - - - - - - - - -				
0	8.5^{a}	11.1^{a}	50.2^{a}	0.7^{a}	neg
9.2	8.9^{a}	10.8^{a}	52.4^{ab}	1.8^{b}	neg
18.4	13.5^{b}	13.2^{b}	57.0^{b}	2.4^{c}	neg
27.6	17.6^{c}	14.5^{b}	57.8^{b}	3.5^{d}	trace
Significance of treatment effect	**	**	*	**	

Means in the same column with the same letter in the superscript are not significantly different ($P<0.05$) according to Duncans's Multiple Range Test.

Oxalate, one of the potentially toxic components of kochia, showed significant increases with each increase in fertilizer level but did not reach the serious quantities reported from New Mexico ($\geq$4.5%, Karachi et al., 1988). Nitrate, another toxic component, was only present in trace amounts after the highest level of fertilization in this trial.

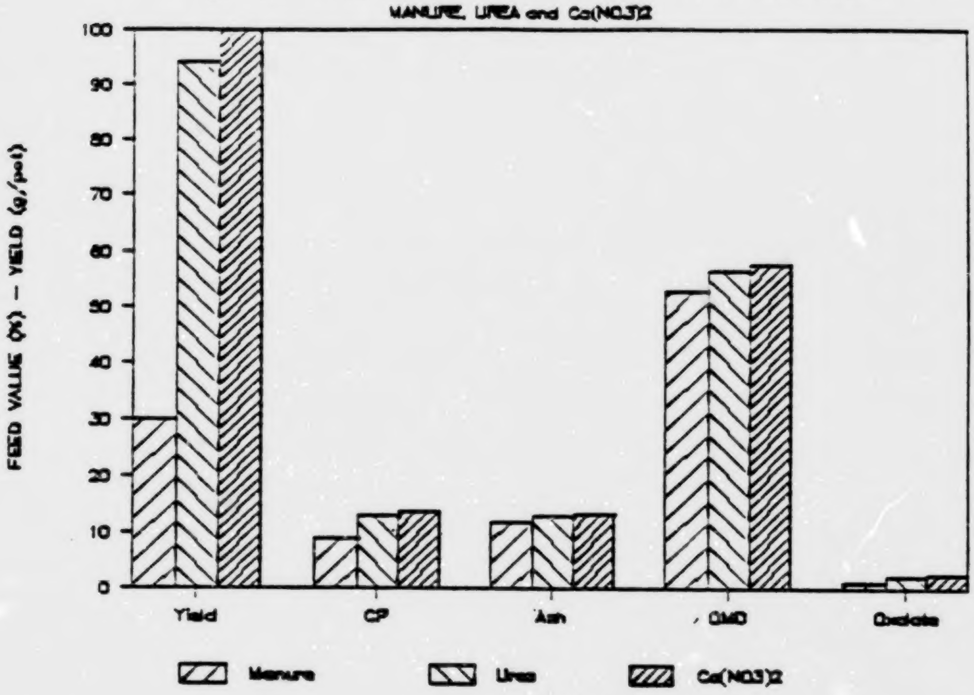
For Trial 2, no significant differences in percentage germination were observed among the three treatments. The addition of semi-dry cattle manure did not affect the yield of kochia forage (Table 6, Figure 2) when compared to the yield of the control (0 g N pot^{-1}) in Table 4. The yields of kochia forage after the addition of the other two fertilizers were significantly greater than after treatment with manure. They were similar in value to yields achieved by the addition of comparable fertilizer levels in Trial 1 (Table 4).

Table 6. The effect of added fertilizer (manure, urea and $Ca(NO_3)_2.4H_2O$) on the dry matter yield of kochia forage.

Added fertilizer (g pot^{-1})		Dry matter yield (g pot^{-1})
Manure	(1023)	30^{a}
Urea	(4.67)	94^{b}
$Ca(NO_3)_2.4H_2O$	(18.4)	100^{b}
Significance of treatment effect		**

Means in the same column with the same letter in the superscript are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

Fig. 2. FERTILIZER ON KOCHIA FORAGE



The feed values for kochia forage following manure fertilization (Table 6) were similar to the values for CP, ash, IVOMD, oxalate, and nitrate for the control (0 fertilizer) reported for Trial 1 (Table 4). With the exception of nitrate, the values obtained following addition of the other two fertilizers (Table 7, Figure 2) were all significantly higher than found for manure. These values were also similar to those obtained from comparable fertilizer levels used in Trial 1 (Table 4).

Table 7. Effect of added fertilizer (manure, urea and $Ca(NO_3)_2.4H_2O$) on some nutritional and toxic components of kochia forage.

Fertilizer (g pot^{-1})	CP	Ash	IVOMD	Oxalate	Nitrate
	% of DM				
Manure (1023)	8.8^a	11.9^a	52.7^a	1.1^a	neg
Urea (4.67)	12.9^b	13.1^b	56.4^b	2.5^b	neg
$Ca(NO_3)_2.4H_2O$ (18.4)	13.6^b	13.2^b	57.6^b	2.8^b	neg
Significance of treatment effect	**	**	**	**	

Means in the same column with the same letter in the superscript are not significantly different ($P<0.05$) according to Duncans's Multiple Range Test.

CONCLUSIONS

The crude protein, ash, and digestibility of kochia forage varied directly with increasing levels of nitrate fertilizer. This may be due to an increase in the leaf to stem ratio (which was not measured). The manure did not have any effect on the nutritional value of kochia forage.

Even though the plants were not under any stress, the increase in oxalate content was significant and varied directly with the level of nitrogen fertilization (see Chapter 4). In Trial 1, the oxalate content was approaching toxic levels when the largest amount of nitrogen fertilizer was used. However, this would not cause a feeding problem if kochia was fed at less than 50% of the ration. Heat or drought stress might cause the oxalate content to be even higher, but this is only speculation at this point and trials would have to be conducted under stressful conditions to investigate this possibility.

Since soluble oxalate can now be measured quickly by NIRS at the FTL, farmers should ask for oxalate content in kochia samples submitted for analysis. Ration levels of kochia, other ingredients and/or an oxalate-counteracting, dicalcium phosphate supplement (Kingsbury, 1964) can then be recommended by the FTL.

The fact that traces of nitrate were detected only at the highest level of nitrogen fertilization indicated that this fertilizer can affect nitrate accumulation at least to a minimal extent, even though the kochia was not growing under any stress whatsoever. Nitrates are accumulated in plants under stress, and trials comparing nitrate and ammonia type fertilizers should be conducted using higher amounts of fertilizer and run under heat, moisture and chemical stress to determine if the fertilizer type has any practical effect on nitrate accumulation.

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B. FIELD EXPERIMENTS TO EVALUATE THE RESPONSE OF KOCHIA TO NITROGEN FERTILIZER WHEN GROWN ON SALINE SOIL.

by

D. Green, H. Steppuhn and J.A. Kernan

ABSTRACT

Three experiments to determine the effect of nitrogen fertilizer on the yield of kochia were conducted near Swift Current, Saskatchewan in 1987. One of the trials was also used to determine the effect on the nutritive value of kochia.

For Trial 1, levels of 0, 56, and 112 kg N ha^{-1} were broadcast at seeding (May 15). The dry matter yield and crude protein content were significantly ($P<0.01$) increased by fertilizer N, as was the oxalate content, although the latter did not reach a toxic level. The in vitro organic matter digestibility was not affected by the level of nitrogen fertilizer. The nitrate test was negative, even at the highest level of applied N fertilizer.

For Trials 2 and 3, levels of 0, 56, 112, and 168 kg N ha^{-1} were broadcast on July 10 (Trial 2) and 0, 56 and 112 kg N ha^{-1} were broadcast on June 18 (Trial 3). The yield improvement for Trials 2 and 3 was significant ($P<0.01$), but was less than achieved in Trial 1, probably due to applying the fertilizer later in the season.

Net income to nitrogen fertilizer costs was increased by fertilizer for all trials, with the greatest increase occurring with the first 56 kg of N.

INTRODUCTION

Field trials were conducted in 1987 near Swift Current, Sask., to evaluate the response of kochia to nitrogen fertilizer when kochia was grown on a saline affected soil. These results were be compared to the pot trials conducted in Saskatoon using a non-saline soil (Section A of this chapter). The pot trials were conducted in an irrigated mode, i.e., soil moisture was maintained at near field capacity throughout the growing period. In contrast, the field trials at Swift Current were grown under rain-fed conditions. Since both nitrate and oxalate appeared from earlier studies to be affected by soil fertility, the field trials were an opportunity to evaluate the tendency of kochia to accumulate these potential toxins under various fertilizer level conditions.

MATERIALS AND METHODS

Trial 1

A saline gradient site was selected on the Vance farm, approximately 15 km north of Swift Current. Forty-five kg P_2O_5 ha^{-1} and 0, 56 and 116 kg N ha^{-1} (ammonium nitrate) were broadcast onto the site and incorporated into the soil by cultivation followed by harrowing before seeding. The experiment was designed as a randomized complete block (4 replicates) with fertilizer N rate as the variable. Plots were arranged up the saline gradient slope.

Unselected Saskatchewan kochia seed, obtained from a farmer at Success, Saskatchewan, was seeded at a rate of 3.4-4.5 kg ha^{-1} with a double disc press drill. The seed was metered directly onto the soil surface. The seed was shallowly covered by harrowing using diamond tooth harrows.

Three kochia samples, each cut at ground level from metre squares, were collected from each plot at different slope positions on August 13, 1987. The samples were weighed and mean dry matter yields determined for each plot. The three samples from each individual plot were combined, hammermilled through a 1.25 cm screen and ground through a 1 mm screen on a Wiley Mill. Representative sub-samples from each plot were submitted to the Feed Testing Laboratory of the University of Saskatchewan for analysis for moisture, crude protein (CP) [A.O.A.C., 1984, (N x 6.25)], Ash (A.O.A.C., 1984a), and in vitro organic matter digestibility (IVOMD) [Troelsen, 1971; modification of the method of Tilley and Terry, 1963].

The results for yield and nutritive value were statistically analyzed by a two-way analysis of variance and Duncan's multiple range test.

Trial 2 and Trial 3

These experiments were also conducted as randomized complete blocks at the same general location as Trial 1. In Trial 2 the fertilizer treatments were 0, 56, and 112 kg N ha^{-1} (ammonium nitrate) and summerfallow (no crop). In Trial 3, the fertilizer treatments were 0, 56, 112, and 168 kg N ha^{-1} (ammonium nitrate). Phosphate fertilizer (45 kg P_2O_5) was broadcast and incorporated into all plots before planting kochia. In Trial 2, the nitrogen fertilizer was broadcast on June 18, 1987. In Trial 3, N fertilizer was broadcast on July 10, 1987. Kochia seed was planted as described for Trial 1.

The yield data was analyzed statistically as described for Trial 1.

RESULTS AND DISCUSSION

Trial 1

The above ground yield (Table 1, Figure 1), the CP, ash, and oxalate contents (Table 1) were all significantly increased by the addition of nitrogen fertilizer. There was no significant affect on the IVOMD of kochia.

The CP content of the kochia forage was very low, consistent with the hypothesis that the kochia was cut at too late a stage of maturity. The highest rate of N fertilizer applied (112 kg N ha^{-1}) significantly improved both yield and CP, but still did not cause the development of detectable levels of nitrate in the forage (Table 1).

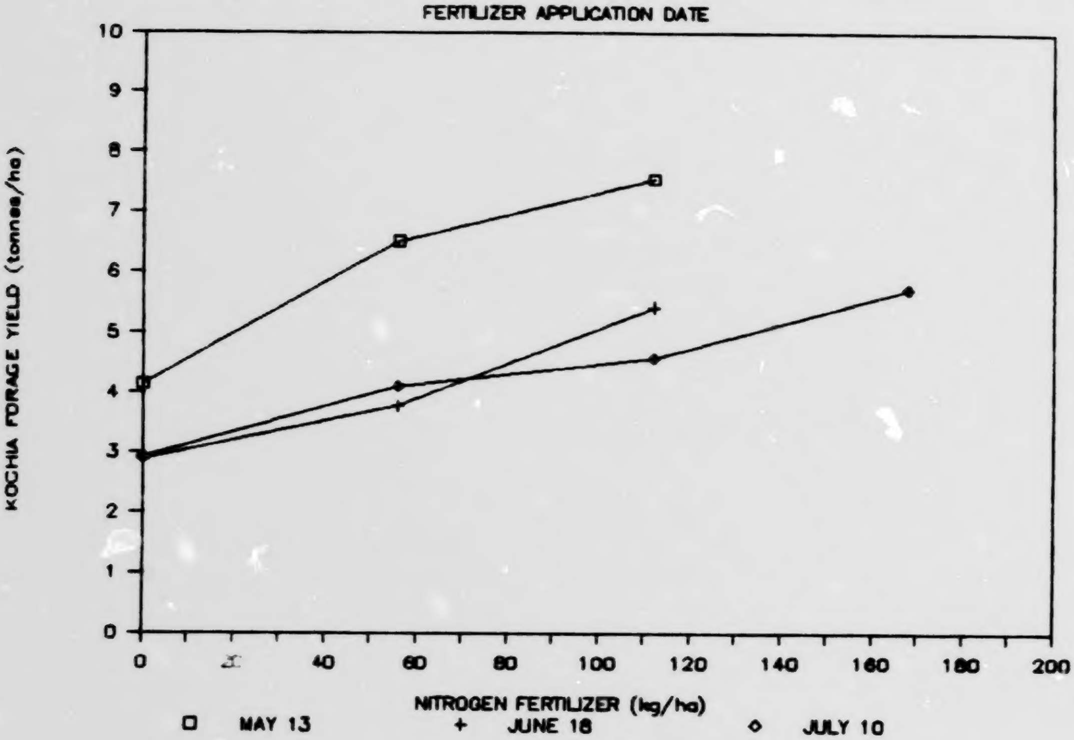
Table 1. The effect of nitrogen fertilization at seeding (May 15) on the yield, nutritive value, and oxalate content of Saskatchewan kochia grown near Swift Current in 1987 (all results are recorded as dry matter).

Nitrogen fertilizer rate (kg ha^{-1})	Yield (tonnes ha^{-1})	CP	Ash	IVOMD	Oxalate	Nitrate
		- - - - - - - -	- - - -	% of DM	- - - -	- - - -
0	4.15	7.5^a	10.9^a	52.3	1.7^a	negative[1]
56	6.51	8.3^b	11.1^{ab}	51.9	1.7^a	negative
112	7.56	10.2^c	11.8^b	52.7	2.2^b	negative
Significance of fertilizer effect	**	**	**	NS	**	

Means within a column with the same letter in the superscript are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

[1] Spot test for nitrate was negative, therefore quantitative analysis were not done.

Fig. 1. N FERTILIZER – KOCHIA YIELD



Under the conditions of this experiment both rates of N fertilizer gave a positive return on investment (Table 2), with the greatest increase in net income occurring with the first increment of 56 kg N fertilizer. The greatest increase in crude protein content occurred with the second increment of N fertilizer.

Table 2. The economics of applying nitrogen fertilizer (Trial 1).

Nitrogen fertilizer rate (kg ha^{-1})	Yield kochia (tonnes ha^{-1})	Fertilizer cost ($) @ $0.55 kg^{-1} N	Hay value ($) @ $55 tonne^{-1}	$ Net income to fertilizer costs
0	4.15	0	228	228
56	6.51	30	358	327
112	7.56	62	416	354

Trial 2

The improvements realized for Trial 2 and Trial 3 were not as great as that realized for Trial 1, which may be due to the later application of the nitrogen fertilizer (Table 3, Figure 1). The reduced yield improvement with nitrogen fertilization also reduced the net improvement in income compared to Trial 1.

Since Trials 1, 2 and 3 were not done as part of the same experiment, comparisons between them are of a general observational nature only. The yield data would suggest that the earliest date of fertilizer application gave the largest increase in yield, although the fertilizer N was incorporated in Trial 1, whereas it was broadcast in Trials 2 and 3.

Further experiments should be conducted to evaluate the effects of fertilizer application method, and to separately evaluate N fertilizer date of application. The initial observation, from these experiments, is that application of N fertilizer at the date of seeding is probably the best approach.

Table 3. The effect of nitrogen fertilization on the yield of kochia hay grown near Swift Current in 1987, and the economics of the fertilizer application (Trials 2 and 3).

Nitrogen fertilizer rate (kg ha^{-1})	Yield kochia (tonnes ha^{-1})		Fertilizer cost @ \$0.55 kg^{-1} N	Value (\$) @ \$55 tonne^{-1}		\$ Net income to fertilizer costs	
	Trial 2	Trial 3		Trial 2	Trial 3	Trial 2	Trial 3
0	2.88^{a}	2.92^{a}	0	158	161	158	161
56	3.78^{ab}	4.11^{b}	31	208	226	177	195
112	5.43^{b}	4.59^{b}	62	299	252	237	191
168	-	4.94^{b}	92	-	272	-	179
Significance of fertilizer effect	**	**	—	—	—	—	—

Means within a column with the same letter in the superscript are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

One of the objectives of the fertilizer experiments was to test for the tendency of kochia to accumulate nitrate under conditions of high available soil nitrate. We were not able to induce kochia to accumulate significant amounts of nitrate under the conditions of these experiments. Only in the pot trial with various levels of nitrate fertilizer (section A, first experiment) did the highest level of nitrate fertilizer start producing detectable amounts of nitrate in kochia forage.

In contrast, soluble oxalate levels were highly correlated to crude protein levels (Chapter 4). As fertilizer increased CP in kochia, it also increased soluble oxalate.

Levels of soluble oxalate intake in the diet up to 0.2% of the animal's weight can be ingested without effect if taken in small amounts over the day (see Chapter 4). The amounts of soluble oxalate in these experiments (sections A and B of this chapter) ranged from 2.2% to 3.5%. A 1000 lb (454 kg) cow eating 25 lbs per day (11.3 kg per day) of kochia containing 3% soluble oxalate, would consume 0.075% of her weight of soluble oxalate. This would appear to be well within the limits suggested.

Other factors (such as alkaloid) need to be tested for their relationship to nitrogen fertilizer response of kochia and to animal problems when kochia is fed at more than 40-50% of the diet (see Chapter 7).

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CHAPTER 11

AFFECT OF HERBICIDES, TYPE OF KOCHIA, SEEDING DATE, AND POSITION ON SALINE GRADIENT, ON THE YIELD OF KOCHIA FORAGE

by

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ABSTRACT

Various herbicides were tested for their ability to control other plant species in sown and managed stands of kochia. All grassy and broadleaf herbicides tested, i.e. sprayed onto stands of young established kochia, suppressed yields of kochia forage. The herbicide which suppressed kochia yield the most was Glean, but even in this case, plants did survive

This kochia was seeded on saline land which had grown kochia the previous year. The site was cultivated in the fall. Fall seeded kochia did not yield as well as kochia seeded on April 29th, which in turn was much poorer in yield than kochia sown on May 29. Kochia early growth was suppressed by soil which had recently grown kochia, flixweed or stinkweed. Cultivation followed by a period of old kochia plant residue decay seems necessary to obtain good stands of kochia following kochia. Winter annual weeds of the mustard family need to be controlled to allow kochia to establish well. The best yields of kochia, and the least variation in yield up a saline gradient, was obtained by seeding kochia in late spring into cultivated ground, free of other plant species, and without the subsequent use of herbicides.

INTRODUCTION

A saline site north of Swift Current (Vance site) was selected for this study. The primary objective of the study was to test the tolerance of growing kochia to a variety of annual grassy and broadleaf herbicides. Secondary objectives were to compare Texas and local selections of kochia in their tolerance to herbicides, to compare the affect of two or three seeding dates (late fall, early spring, late spring) on the yield of kochia forage, and to measure the influence of saline slope position (upper, mid, low slope positions)on the other factors. All these factors were considered important in developing reliable production techniques for kochia forage on saline affected fields.

MATERIALS AND METHODS

The site was gently rolling, sloping down to a saline slough. The area, in the previous year (1985), had grown mixed weeds, mainly kochia. Kochia had been cut, baled and removed as forage. The site was cultivated in early fall. Kochia was planted at a very shallow depth (<0.5 cm) at three dates: late fall (October 29, 1985), early spring (April 29, 1986) and late spring/early summer (May 29, 1986).

No fertilizer was applied to the site.

Herbicides were applied at recommended rates after the kochia was well established and about 25-30 cm tall (early July). Herbicides tested were (by trade name), Sencor 500 (Metribuzin), MCPA, Stampede 360 (propanil), Control, Glean (chlorsulfuron), 2,4-D, Tordon 202 (picloram + 2,4-D), Senbar (terbacil), Check.

Two types of kochia were planted, a Texas selection (seed from A. Nieto, Hereford, Texas) and a Saskatchewan source (unselected local wild plants harvested by D. Marin, Radville, Saskatchewan). Texas kochia was planted only at the April and May dates.

Experiments were repeated in three fold replication in a randomized complete block. Replicates were arranged up the saline slope with replicate 1 at the base of the slope and replicate 3 at the top most position up the slope.

Plants were harvested in early September and air dried. Yields are reported on an air dried basis.

RESULTS

1. General Observations

Field observations of kochia-weed interactions suggested weeds such as flixweed and stinkweed might inhibit kochia establishment. To test this hypothesis, soil (top 0-5 cm) was collected and placed in flats for greenhouse testing. Soil from sites containing flixweed, stinkweed, kochia, wheat stubble, foxtail barley, quackgrass, or silverweed (Potentilla anserina, L.) was levelled in seeding flats, and compacted prior to seeding with Sk* kochia (600 seeds yd^{-2}, 785 seeds m^{-2}). The flats were watered. Measurements on seedling emergence and growth were taken at regular intervals. Several interesting observations were made. Kochia established slowly on kochia, flixweed or stinkweed contaminated soils. Quackgrass, foxtail barley, silverweed and wheat stubble were not detrimental to kochia establishment. These observations confirmed the field observations. Kochia has already been reported to be autoallelopathic (Lodhi, 1979) i.e plants release chemicals which hinder the growth of next year's young plants.

Soil disturbance may also have a beneficial effect on removing allelopathic inhibitors from the soil. A number of observations in Texas and New Mexico imply that some degree of soil disturbance is important to control kochia plant numbers and remove soil phytotoxins. With soil disturbance each year at planting, it appears possible to grow kochia on the same site for at least several years in a row (Durham and

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* Sk = Saskatchewan

Durham, 1979, and 1986 field trip to Texas). This soil disturbance was tested and confirmed in 1987 (see Chapter 5).

This preliminary experiment is consistent with field observations of Mr. K. Lepoudre. (Saskatchewan Agriculture representative at Davidson, Saskatchewan) (phone call to E.C. September 5, 1986). On saline sites (cultivated soil) which were sprayed in the fall with 2,4-D to control winter annuals (such as flixweed and stinkweed), a good stand of kochia established well in the early spring and grew vigorously. On sites not sprayed in the fall with 2,4-D, winter annuals grew vigorously and kochia growth next spring was sparse and poor.

These observations suggest that winter annuals and early spring germinating weeds must be controlled if a good stand of kochia is to be obtained.

2. Effects of Herbicides

Table 1 shows yields of kochia as affected by herbicide and kochia seeding date.

Table 1. Yield of kochia forage. Effects of herbicide and kochia seeding date (average of Saskatchewan and Texas kochia types).

Herbicide	Kochia yield (kg ha^{-1}) Seeding date April 29	 May 29	 Average
Sencor	3158	3617	3388^{ab}
MCPA	4050	5508	4779^{bc}
Stampede	3867	6233	5050^{c}
Control	2733	6475	4604^{bc}
Glean	2950	2542	2746^{a}
2,4-D	2017	4717	3367^{ab}
Tordon	1925	5408	3667^{abc}
Check	1858	7808	4833^{bc}
Sinbar	1842	6617	4229^{abc}
Mean	2711	5436	4074

Means within a column with the same superscript are not significantly different at the 5% level according to Duncan's Multiple Range Test.

The date of planting was highly significant ($P<0.05$) in its effect on kochia yield. Plots were cultivated before seeding kochia (at each date) and it is possible that winter annuals and other interfering weeds were more effectively destroyed at the later seeding date. The upper slope positions (where weeds were most prolific), were the most affected by date of seeding (Table 2 and Table 3).

Table 2. Effect of date of seeding and type of kochia on yield of kochia forage (kg ha^{-1}).

Type of kochia	Date of seeding April 29	May 29	Mean
Saskatchewan	2448	5609	4029
Texas	2974	5263	4119
Mean	2711	5436	4074

Table 3. Effect of saline slope position and date of seeding, on yield of kochia forage (kg ha^{-1}).

Slope position	Date of seeding April 29	May 29	Mean
Base of slope	4342	6433	5388
Mid-slope	1669	4106	2888
Top of slope	2122	5769	3946
Mean	2711	5436	4074

The main effect of the later date of planting was to increase yields on the upper slope positions (see Table 3), although all slope positions were affected.

Saskatchewan kochia was seeded on three dates, including late fall. The effects of seeding date and herbicides on the yield of Saskatchewan kochia are shown in Table 4.

Table 4. Effect of herbicide and seeding date on yields of Saskatchewan kochia forage (kg ha^{-1}).

Herbicide	Seeding date October 29	April 29	May 29	Mean
Sencor	2183	2933	3617	2911^{ab}
MCPA	2150	2500	6117	3589^{ab}
Stampede	2800	3333	5750	3961^{ab}
Control	2067	2933	6383	3794^{ab}
Glean	2050	2417	2900	2456^{a}
2,4-D	2100	2433	4550	3028^{ab}
Tordon	1783	1883	5050	2906^{ab}
Check	1617	1750	9183	4183^{b}
Sinbar	1617	1850	6933	3467^{ab}
Mean	2041	2448	5609	3366

Means within a column with the same superscript are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Kochia planted on May 29th yielding significantly more than kochia planted on October 29th or April 29th, neither of which latter dates were significantly different from each other.

All herbicides tested adversely affected the yield of kochia. Effects, and differences, were most pronounced at the May 29th seeding data. Kochia planted at this date was growing more vigorously, but was also younger than kochia from earlier seeding dates.

The check yield from the May 29th seeding was 9183 kg ha^{-1} (4.1 tons per acre), a yield considered within the target yield range of 4-5 tons per acre on saline soils (9000-11200 kg ha^{-1}). Individual plots of the check test yielded 9400 (most saline), 6500 (mid slope) and 11650 (upper slope) kg ha^{-1}, at the May 29th planting. Yield variation with slope position was much less at this planting date than at the April 29th planting, where there was a 5-fold difference in yield depending on slope position.

SUMMARY

All herbicides tested adversely affected kochia yield. Planting date had a substantial effect on yield with the highest yields obtained from the May 29th planting. The highest yields were obtained with Saskatchewan kochia planted on May 29th with no herbicide. Based on the May 29th seeding date, the Texas and Saskatchewan kochia responded as shown below to the herbicides tested (Table 5).

It would be desirable to repeat some of the herbicide tests on non-saline soil so that the variable effects of soil salinity in the replications were removed.

Table 5. Comparison of the effects of various herbicides on the yield (kg ha^{-1}) of Saskatchewan and Texas kochia planted on May 29th, 1986.

	Kochia type	
Herbicide	Saskatchewan	Texas
Sencor	3617	3617
MCPA	6117	4900
Stampede	5750	6717
Control	6383	6567
Glean	2900	2183
2,4-D	4550	4883
Tordon	5050	5767
Check	9183	6433
Sinbar	6933	6300

Further studies would be desirable to explore the factors responsible for the higher yields from May 29th seeding. Factors to be tested include:

(a) presence or absence of winter annual and other weeds (this should be supplemented by growth room studies for kochia X winter annual interactions).

(b) amount and time of soil disturbance prior to planting kochia.

(c) photo period response, i.e., when other factors are removed, does kochia grow faster and yield more, when planted later in the spring?

(d) relationship to planting date and moisture (rain or irrigation).

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CHAPTER 12

EFFECT OF STAGE OF MATURITY ON YIELD, FEED VALUE AND CONSTITUENTS OF KOCHIA FORAGE GROWN ON A SALINE SOIL

by

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SUMMARY

The best compromise between yield and feed value of kochia at which to harvest for forage appears to be late bud to early flower (usually late July or early August). This stage of maturity at harvest would favor some reduction in nitrate and oxalate. The levels of these potentially toxic substances were not considered serious in the kochia grown in this study, particularly if the kochia was kept as less than 50% of the diet. The high plant density used in this study may have been a factor in keeping the stem size small at the later stages of maturity and in keeping the feed value relatively high into the later stages of maturity.

Saponins and flavonols increased with increasing maturity, whereas phenolic acids decreased. There is not sufficient evidence to indicate whether these components of kochia are a factor in feed value or are antinutritive in their effect. The available evidence from New Mexico would imply that alkaloids, oxalate, and nitrates are the main toxic factors. Plant selections for low alkaloid, agronomic management to minimize nitrate, harvest at the appropriate stage, and dilution of kochia with other feeds are the main tools available to enable kochia to be used safely and effectively.

INTRODUCTION

Kochia has had a mixed history as a forage. Studies in South Dakota (Erickson and Moxon, 1947), Saskatchewan (Bell et al., 1952), and Texas (Sherrod, 1971, 1973) have suggested its use as a drought resistant forage. Farm experience in Texas (Durham and Durham, 1979) and Saskatchewan (Hanson, 1988) indicated that kochia could be used on a long term basis as a cattle feed, although the Saskatchewan farm survey (Hanson, 1988) strongly suggested that kochia should be kept below 50% of the total diet.

On the other hand, a number of reports described toxic effects to animal eating kochia. Reports from Argentina (Souto and Milano, 1966), Colorado (Dickie and James, 1983), and New Mexico (Karachi et al., 1986, 1988) described toxicity problems with cattle eating kochia, particularly when it constituted a large part of the diet and when it was growing under high fertility conditions.

Therefore it was considered important in this study to not only evaluate the yield, digestibility and protein content of kochia harvested at various stages of maturity (c.f. Sherrod, 1971), but also to determine how the stage of maturity of kochia, grown on saline soil, affected the percentages of various potential toxins.

The objective of this study was to measure the yield and feed value of kochia harvested at five stages of maturity, when grown on a saline site.

In addition, a variety of possible toxins were measured in these kochia samples to determine their content and how they varied with the stage of maturity and the seed source of the forage. Possible toxins included the following:

1. Nitrate (Karachi et al., 1988),
2. Oxalate (Karachi et al., 1988),
3. Alkaloids (Karachi et al., 1988),
4. Saponins (Souto and Milano, 1966),
5. Phenolic acids (Borneman, Akin and Van Eseltine, 1986).

In addition to the possible presence of these materials, which might be toxic to cattle, flavonoids (particular types of phenols found in plants) have been found in kochia before and were implicated, along with phenolic acids, as being natural herbicides which could interfere with growth of a following crop (Lodhi, 1979). Some flavonoids have been identified as insect feeding deterrents, and it is known that grasshoppers prefer to eat other forages in preference to kochia (see Chapter 3, page 18-19). Therefore flavonoids were measured also.

These studies were part of a general plan to improve kochia feed value by:

1. Determining the best stage to cut to optimize feed value and yield.
2. Determining the amounts of possible toxins and determining if the amounts can be reduced by selecting the stage of maturity to cut or the source of seed.

3. Maintaining grasshopper feeding deterrent activities in improved selected kochia.

MATERIALS AND METHODS

Kochia was grown on the Rempel site (Swift Current, Saskatchewan) in 1985. The kochia used in these analyses was grown on a severely saline soil. Kochia grew on the site in 1983 and 1984. The soil was rotovated once in late fall (end of September of 1984) and left undisturbed the following spring. Kochia seed present in the rotovated seed bed germinated the following spring. Establishment was very successful with a high plant density (400 to 700 plantsm^{-2}). No fertilizer was applied to the site.

Some yellowing of the kochia forage occurred. This may have been caused by the decomposition of previous kochia residue in the soil (autoallelopathy) or from too high a plant population.

Representative samples (six replicates) were harvested on the following dates:

5 July 1985:	Prebud
15 July 1985:	Mid bud to early flower
31 July 1985:	Full bloom
16 August 1985:	Fruits about half developed
1 October 1985:	Mature seed stage. Most of seed lost to shattering. Most of leaves still on the plant but leaves brown.

Alfalfa was harvested at 10% bloom, in 1985, at the Swift Current Research Station on a non saline site, as a reference material (6 replicates). Only one cut was obtained (drought in 1985).

All samples were air dried and sent to Saskatoon for analyses.

All samples were examined by J. Hudson, Saskatchewan Research Council, to determine stage of maturity.

Feed analyses were conducted using standard AOAC methods. Rumen fluid digestibility, nitrates, and crude protein contents were analyzed at the Feed Testing Laboratory, University of Saskatchewan. Saponins, phenolic acids, and flavonoids were analyzed by standard methods in the literature, after suitable modifications where necessary (Sosulski, 1988). Oxalate was determined by near infrared reflectance spectroscopy (Sugg, Cuesta and Norcross, 1983) after calibration of the instrument using samples analyzed by the method of Dye (1956).

RESULTS

1. Yields and Feed Value

Although plants were very crowded on the 1985 salinity site (400-700 plants m^{-2}) the forage yield was quite good (up to 7 tonnes ha^{-1}) (Table 1).

The percent leaf stayed very high, even into the later stages of maturity (e.g. late flower) (Table 1).

This high percentage of leaf may be one reason why forage protein and forage digestibility of kochia were quite high in this experiment (Table 2). Organic matter digestibility of kochia was higher than alfalfa, but the much higher ash in kochia would reduce the available digestible organic matter in the dry matter more than in alfalfa.

The yield of alfalfa in 1985 was considerably lower than kochia. We believe this difference reflects kochia's ability to utilize moisture on saline sites even when drought (as in 1985 at Swift Current) restricted the growth of conventional forages (not halophytes) on non-saline soils.

Kochia leaves had similar crude protein contents at early stages of maturity, to alfalfa (Table 3). The ash content of kochia leaves was almost twice as high as alfalfa. Kochia stems were much lower in protein and ash than leaves. Thus aiming at very leafy kochia cultivars, or cutting at earlier stages of maturity, would tend to increase protein but also ash.

Table 1. Effect of maturity on yield and % leaf of kochia and comparison with alfalfa harvested at 10% bloom.

Crop	Maturity	Whole plant yield (tonnes ha^{-1})	Leaf yield (tonnes ha^{-1})	Stem yield (tonnes ha^{-1})	% Leaf
Alfalfa	10% bloom	2.87	1.48	1.30	42
Kochia	prebud	4.38^{ab}	2.26^{ab}	1.45^{a}	52^{b}
	bud	6.10^{b}	2.94^{bc}	2.44^{b}	48^{ab}
	early flower	6.63^{c}	3.35^{c}	2.78^{b}	52^{b}
	late flower	7.16^{c}	3.66^{c}	2.71^{b}	51^{b}
	mature	6.12^{bc}	2.69^{b}	2.81^{b}	43^{a}
Significant of maturity effect		**	**	**	*

Means within a column with the same subscript are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 2. Effect of maturity on crude protein and digestibility of whole kochia and comparison with whole alfalfa harvested at 10% bloom (all results expressed as dry matter).

Crop	Maturity	CP (%)	ASH (%)	IVOMD (%)	IVDOM (%)	TDN (%)
Alfalfa	10% Bloom	17.7	10.0	56.9	51.2	57.6
Kochia	prebud	15.7^{c}	16.6^{b}	65.0^{bc}	54.2^{bc}	65.9^{bc}
	bud	16.1^{c}	16.3^{b}	69.6^{c}	58.3^{c}	70.6^{c}
	early flower	12.9^{b}	15.8^{b}	62.8^{b}	52.8^{b}	63.7^{b}
	late flower	10.4^{ab}	13.0^{a}	63.2^{b}	55.0^{bc}	64.0^{b}
	mature	8.0^{a}	15.6^{ab}	54.9^{a}	46.4^{a}	55.7^{a}
Significance of maturity effect		**	**	**	**	**

Means within a column with the same superscript are not significantly different at the 5% level according to Duncan's Multiple Range Test.

CP = crude protein
IVOMD = in vitro organic matter digestibility
IVDOM = in vitro digestible organic matter
TDN = total digestible nutrients

Table 3. Effect of maturity on crude protein of kochia leaf and stem and comparison with alfalfa harvested at 10% bloom.

		Leaf		Stem	
Crop	Maturity	CP(%)	ASH (%)	CP(%)	ASH (%)
Alfalfa	10% bloom	22.5	11.0	18.5	9.6
Kochia	prebud	22.8^{c}	20.9	10.4	14.9^{b}
	bud	23.0^{c}	19.6	9.2	13.5^{ab}
	early flower	19.5^{bc}	20.3	8.1	12.3^{a}
	late flower	15.4^{ab}	17.2	7.6	10.9^{ab}
	mature	11.0^{a}	18.1	7.9	14.5^{b}
Significance of maturity effect		**	NS	NS	**

Means within a column with the same superscript are not significantly different at the 5% level according to Duncan's Multiple Range Test.

2. Nitrates

Nitrates tended to be accumulated in the stems, with a tendency to be highest at the early stages of maturity (Table 4).

Table 4. Amounts of nitrate in kochia forage at five stages of maturity.

Stage of maturity and harvest date	Average % of nitrate (dry matter basis)		
	Leaves	Stems	Whole forage
Prebud (July 7)	0.11	0.41	0.37
Bud (July 16)	0.16	0.50	0.40
Early flower (July 31)	0.04	0.18	0.08
Late flower (August 16)	-	-	Trace
Mature seed (October 1)	-	-	0.14

Since feed value was still good at early flower (Table 2) and yields were higher at early flower than preceding stages, cutting kochia at early flower would have reduced nitrate levels significantly.

Studies of kochia in New Mexico (Karachi et al., 1988) also found that percent of nitrate in kochia decreased as the plants become more mature. Levels of nitrate of 0.5% (as nitrate nitrogen) can cause chronic toxicity (Karachi et al., 1988) and levels of 1% or more can cause acute toxicity. Amounts of nitrate as high as 2% (equivalent to 0.45% nitrate nitrogen) were reported from fertilized and irrigated kochia in New Mexico (Karachi et al., 1988).

Most farmer samples of kochia contained less than 0.5% nitrate (Chapter 6). However, two trials with irrigated and fertilized kochia in western Canada (Chapter 6) produced kochia with more than 2% nitrate. These results, and similar results from New Mexico, suggest that kochia can accumulate potentially toxic levels of nitrate under conditions of high soil nitrogen fertility.

3. Fiber Content

Fiber varied with stage of maturity as shown in Table 5.

Table 5. Effect of stage of maturity of kochia forage on fiber content.

Stage of maturity	Fiber component % air dry basis		
	NDF[1]	ADF[2]	Hemicellulose
Prebud	32.3	18.0	14.3
Bud	35.0	19.7	15.3
Early Flower	40.3	20.9	19.4
Late Flower	41.2	22.1	19.1
Mature	54.2	27.6	26.6

[1] NDF = neutral detergent fiber
[2] ADF = acid detergent fiber

Increases in fiber content were consistent with the decreases in digestibility shown in Table 2.

4. Saponins

Saponin content in kochia at five stages of maturity is shown in Table 6.

Table 6. Saponin content of kochia forage at five stages of maturity in 1985.

Stage of maturity	Saponin content Haemolytic activity units g^{-1}
Prebud	1.63
Bud	1.54
Early Flower	2.17
Late Flower	3.14
Mature[1]	2.02

[1] Seed lost by shattering, leaves still present.

Saponin appeared to be concentrated in the seed (Table 7).

Table 7. Saponin content in kochia seed.

Seed source	Saponin content Haemolytic activity units g^{-1}
Saskatoon	6.15
Swift Current	6.73
Texas	5.52

It was noteworthy that kochia forage grown in Saskatchewan from Texas seed, and non-flowering here, still showed high levels of saponin even although no seed formed.

More analyses should be done to give more information on saponin contents and the relationship of saponin content to seed source, growing conditions, and stage of maturity. The evidence to date suggests that saponin content increases in the later stages of maturity, associated with flowering and seed production.

It is not clear what relationship, if any, saponin content has to toxicity. Studies in New Mexico has indicated that oxalates, nitrates and alkaloid are the principal potential toxins in kochia (Karachi et al., 1986, 1988).

It is not known if saponins may be a factor in grasshopper feeding deterrency in kochia or in the herbicide activity (allelopathy) in this plant. Saponins in alfalfa tops or roots has been shown to inhibit the germination of cotton seeds.

5. Phenolic Acids

The phenolic acid content of kochia, at different stages of maturity, is summarized in Table 8.

Table 8. Phenolic acid content of kochia forage at five stages of maturity.

Stage of maturity	Content of phenolic acid % of DM			
	Free	Esterified	Bound	Total
Prebud	0.04	0.54	0.27	0.86
Bud	0.06	0.49	1.50	2.04
Early flower	0.07	0.33	1.25	1.64
Later flower	0.04	0.07	0.12	0.23
Mature	0.03	0.05	0.08	0.17

Phenolic acid content rose to a peak during bud and flower development and declined thereafter. Free phenolic acid was lowest in concentration, but changed the least with maturity. Esterified phenolic acid was the dominant form in young forage, but were replaced by bound phenolic acid as the dominant form at flowering. Both esterified and bound phenolic acid declined rapidly in concentration as the forage matured.

The identity of individual phenolic acids present was measured by gas-liquid chromatography (GLC). Protocatechuic acid was the major phenolic acid present in free phenolic acid at all stages of maturity.

Protocatechuic and gentisic acids were the major phenolic acids in the esterfied and bound phenolic acid fractions. Ferulic acid was present mainly in bound form (i.e. bound to cell walls) and increased in concentration as the forage became more mature.

Free phenolic acid was concentrated in the leaf, as contrasted to the stem. Esterified and bound forms of phenolic acid were about equally distributed between leaves and stems.

The types and amounts of phenolic acids were unexpected. It will be necessary to check other collections of kochia to determine if the patterns hold for other kochia sources. The phenolic acids should be tested, at the concentrations found here, as natural herbicides (allelopathy) to determine if they make a significant contribution to kochia's herbicide activity.

6. Flavonoid and Tannin

The concentration of these substances found in kochia forage is reported in Table 9. Flavonol was the category of flavonoid measured by the colorimetric method used.

The flavonol concentration increased rapidly between prebud to late flower stages, and were still quite high at the mature seed stage. Tannin were much lower in concentration than flavonol, except at the youngest stage of maturity.

Table 9. Flavonol and tannin in kochia forage at five stages of maturity.

Stage of maturity	Flavonol	Tannin
	- - - - - - % of DM	- - - - - -
Pre-bud	0.08	0.06
Bud	0.10	0.02
Early Flower	0.32	0.04
Later Flower	0.68	0.04
Mature	0.43	0.09

Two flavonols, quercetin and myrcetin, have been identified as potential phytotoxins (natural herbicides or allelochemicals) in kochia (Lodhi, 1979). They should be tested, at the concentrations found here, with and without the phenolic acids found earlier (Table 8), to determine if they can account for the allelopathic effects found for kochia.

Some flavonols, e.g. quercetin, have been reported to have insect feeding deterrent activity (Porter et al., 1986). They should be tested to determine if they are the source of grasshopper feeding deterrency in kochia.

Both flavonol and tannin tended to be concentrated in the leaf fraction of kochia.

7. Oxalate

The content of soluble oxalate decreased as kochia matured (Table 10) and the protein content decreased (see Chapter 4 for correlation between oxalate and protein).

Table 10. Soluble oxalate content of kochia forage at five stages of maturity.

Stage of maturity	Oxalate - - - % of DM - - -
Prebud	3.6
Bud	3.7
Early flower	3.2
Late flower	2.8
Mature	1.7

Similar declines in oxalate were observed in New Mexico studies (Karachi et al., 1988). Absolute contents of oxalate were considerably higher in New Mexico samples, e.g. 4.6 to 6.1% soluble oxalate in forage harvested over a 12 week sampling period. Karachi et al., (1988) reported that oxalate levels exceeding 4.5% are considered potentially toxic to ruminants. If kochia is fed at levels not exceeding 50% of the diet, none of the kochia samples in this stage of maturity study would be considered toxic in oxalate.

SUMMARY

The rise and fall of concentrations of the secondary metabolites (saponin, phenolic acid, flavonol, and tannin) can be summarized as follows:

. Nitrate decreased as the forage matured,
. Phenolic acid decreased as the forage matured,
. Oxalate decreased as the forage matured,
. Tannin was very low and changed little with maturity,
. Saponin increased as the forage matured,
. Flavonol increased as the forage matured.

It is not known at this time what effect on forage feed value or toxicity is exerted by saponin, phenolic acid, flavonol, or tannin. Early work in Argentina (Souto and Milano, 1966) implicated saponin as the cause of toxic symptoms caused by kochia. Recent studies in New Mexico (Smith et al., 1986; Karachi et al., 1986, 1988) have given evidence that nitrate, alkaloid, and oxalate are the main factors causing toxicity. The toxicity levels may vary with management methods; for example, oxalate concentration was reduced by increasing nitrogen fertilizer, and increased by phosphorus fertilizer (particularly at low N fertilizer levels) (Lugg et al., 1983).

We were not able to develop a method for quantitatively analyzing for alkaloid. Karachi et al. (1988) were able to do so. Their data indicated that the alkaloid concentration in kochia declined gradually until the onset of flowering, after which it increased quite rapidly.

CONCLUSIONS

The best compromise between yield and feed value appears to be to harvest at late bud to early flowering. This stage of maturity also would favor some reduction in oxalate and nitrate, two potential toxins in kochia. Based on New Mexico studies this would also be the stage of maturity when alkaloid was the lowest.

Other evidence (see other chapters in this report) indicates that high soil nitrate may lead to nitrate accumulation in kochia.

Future studies are needed to investigate:

1. Interactions between stage of maturity at harvest and fertilizer application.
2. Effects of different planting densities.
3. Selections for low alkaloid lines (already done in New Mexico by Fuehring and Finkner (1984)) and their best stage of maturity for forage harvest.

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CHAPTER 13

THE EFFECT OF MATURITY ON THE NUTRITIVE VALUE, OXALATE AND NITRATE CONTENT OF KOCHIA FORAGE GROWN FROM TEXAS AND SASKATCHEWAN LINES

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ABSTRACT

Texas kochia is being grown in western Canada by a number of farmers since it does not set seed under our long day length conditions. This study was designed to compare its yield and feed value to wild unselected Saskatchewan kochia as used by many farmers. Four replicates of both the Texas and a wild, unselected Saskatchewan line of kochia were planted alternately across a draw, with each replicate divided into four sub-plots. One sub-plot of each replicate was harvested on July 2, July 16, August 10 and September 23, 1987. Dry matter yields were determined, and samples of the last two harvest dates were analyzed for crude protein, ash, in vitro organic matter digestibility, oxalate, and nitrate.

The dry matter yield of the Texas line was only higher than the yield of the Saskatchewan kochia for the September 23 harvest date. At this late harvest date (September 23) Texas kochia was still in the vegetative stage, and had not even progressed to the flowering stage, while the Saskatchewan line had reached full maturity and had produced seed.

There was little difference in the nutritive value between the two lines at the last two harvest dates. Oxalate levels were moderate (1.8-2.8%) and only a trace of nitrate was detected.

Single samples of both lines, harvested at the hay stage of maturity for the Texas kochia, were also grown near Vega, Texas. The crude

protein and digestibility of the Texas line were higher than those of the Saskatchewan line. The crude protein contents of both lines, grown in Texas, were much higher than the values of both lines grown in Saskatchewan. The oxalate content of both lines grown in Texas were also much higher (certainly approaching the toxic range) than was observed for both lines grown in Saskatchewan.

Only traces of nitrate were found in all samples grown at either location. This contrasts to the very high nitrate in Texas kochia found by Derdall in the 1987 farm trial in Saskatchewan (see Chapter 6).

INTRODUCTION

Texas kochia is being grown by a number of western Canadian farmers since it does not set seed under long daylength conditions here, and hence it is free of any weedy spread problems. Wild ecotypes of kochia from northern latitudes require a much shorter growing period to flower than ecotypes from more southern latitudes (Bell et al., 1972).

Kochia, grown without fertilizer in the northern Texas panhandle, appeared to have a higher nutritive value (particularly protein content) than Saskatchewan kochia grown in Saskatchewan based on reports in the literature (Sherrod, 1971; Durham and Durham, 1979). However, Bell et al., (1954) were able to grow several lines of kochia with a high crude protein (CP) content in Saskatchewan. Thus it was unclear whether differences in reported feed values were due to genetic differences, or to differences in soil fertility and/or climate.

It was also unclear whether Texas kochia grown in Saskatchewan would have different potential toxicity problems to local lines. In Texas, much of the local kochia is grazed without any apparent toxic effects to the cattle (Walker and Nieto, 1986; Taylor et al., 1985), although veterinarians in Amarillo, Texas have reported some toxicity problems (Kiesling, 1986). In New Mexico, kochia grown with fertilizer has been responsible for many toxic effects to cows (Kiesling, 1986). Few problems with toxicity have been observed in Saskatchewan where farmers almost always have fed less than 50% of the ration as kochia. One incident occurred when two young calves were fed only kochia hay and the animals died. This could have been due to oxalates, nitrates, alkaloids or saponins since the calves were fed only kochia. It has been recommended that kochia not be fed at more than 50% of the ration for this reason.

In some regions of the Texas panhandle, cattle can graze kochia, or can be fed only kochia chop or hay without encountering any toxicity problems. However in New Mexico, toxic symptoms and reduced growth rates from grazing kochia were very common. Studies in Saskatchewan indicated that drastically reduced intakes and poor performance were observed when local kochia was fed at greater than 50% of the ration. However, the animal intake and performance were normal when kochia was 50% or less of the diet (see Chapter 7). Differences in fertilizer management exist among the three regions which might, to some extent, be responsible for these anomalies. The land in both New Mexico and Saskatchewan must be fertilized to maintain a good yield of kochia high in CP and in vitro organic matter digestibility (IVOMD) (Fuehring, 1984; Lugg et al., 1983). Near Vega, in the Texas panhandle, kochia has been grown on the same land for eight to nine years and the land is still producing good kochia yields with high CP and IVOMD. According to Walker and Nieto (1986) this may be due to a very deep A horizon with a high organic matter content in this region. Perhaps synthetic fertilizer and irrigation (used in New Mexico) tends to increase the toxicity of the plant, although studies in Saskatchewan and New Mexico have not confirmed this hypothesis.

The main objective of this experiment was to compare yields and nutritional composition (mainly CP and IVOMD) of Texas and Saskatchewan kochia grown near Swift Current, Saskatchewan, and to determine the stage of growth which gave the best combination of yield and quality. A secondary objective was to compare the content of two toxic ingredients, nitrate and oxalate, in the two kochia lines. An observation trial was also conducted at Vega, Texas to compare Texas and Saskatchewan kochia grown under Texas soil and climate conditions.

MATERIALS AND METHODS

On May 26, 1987 a field trial was established on a saline gradient site about 10 km north of Swift Current, Saskatchewan, to compare Texas and Saskatchewan lines of kochia. Texas kochia seed was obtained from Adam Nieto of Vega, Texas, and Saskatchewan kochia seed, from unselected wild stands, was obtained from Darald Marin of Radville, Saskatchewan. Four replicates of both lines were planted alternately across a draw with each replicate consisting of four plots. One plot of each replicate for both lines was harvested on July 2, July 16, August 10 and September 23. The samples were dried in a low temperature, forced air oven and the dry matter (DM) yields determined. All samples from the last two harvest dates were hammermilled through a 1.25 cm screen, ground through a 1 mm screen on a Wiley mill [and through a Udy grinder for near infrared reflectance spectroscopic analyses (NIRS) only] for nutritional analyses. Representative samples were submitted to the Feed Testing Laboratory (FTL) at the University of Saskatchewan for CP, ash, IVOMD and oxalate (by NIRS, Shenk et al., 1979), and nitrate analyses. Analyses were conducted at the FTL to provide the calibration base for CP [A.O.A.C. 1984 (N X 6.25)], Ash (A.O.A.C. 1984a) and IVOMD [Troelsen, 1971 (modification of the method of Tilley and Terry, 1963)]. Oxalate analyses for the NIRS calibration base were conducted at the Saskatchewan Research Council (SRC) according to the procedure of Dye (1956). Spot tests to determine the presence of nitrate were a modification of the procedure of Hure and Ortis (1949). When qualitative colorimetric tests for nitrate were positive, nitrate was quantified by a modification of the method of Hoffman and Lundell (1937).

RESULTS AND DISCUSSION

Yield

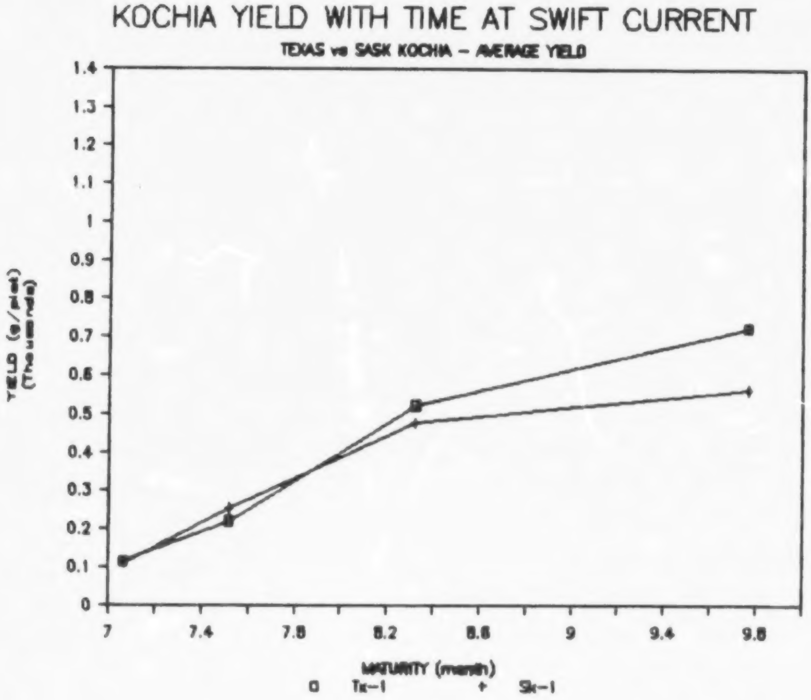
The yield of both Texas and native Saskatchewan kochia, grown in Saskatchewan, increased linearly from July 2 to August 10, 1987 (Table 1, Figure 1). The physiological stage of maturity at harvest for the Saskatchewan kochia was bud, early flower, flower, and mature seed for July 2, July 16, August 10, and September 23 respectively. The Texas kochia remained in the vegetative stage until September 23, due to a phototropic effect on maturity, at which time it had only reached the prebud stage of maturity. The Texas kochia was in the early flower stage in October when it was killed by frost. Up to August 10, the yields of both lines were very similar. Both yields continued to increase, but at a much slower rate, from August 10 to September 23, 1987. The rate of increase in growth during this latter period was greater for the Texas line than for the Saskatchewan line. The Saskatchewan line had matured and produced seed while the Texas line remained in the vegetative stage. The only significant difference in yield ($P<0.01$) occurred at the last stage of maturity, harvested on September 23.

Table 1. Effect of maturity on yield of Texas and Saskatchewan kochia grown at Swift Current in 1987.

Line	Yield (kg ha^{-1})				Significance of maturity effect
	July 2	July 16	Aug. 10	Sept. 23	
Texas	1150^a	2200^a	5220^b	7250^c	**
Sask.	1140^a	2550^b	4770^c	5630^c	**
Significance of line effect	NS	NS	NS	**	

Means with the same letter in a row are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

Figure 1



(To convert g $plot^{-1}$ to kg ha^{-1} multiply by 10).

Composition

Only the samples harvested on August 10 and September 23, 1987 were analyzed to determine their feed value. There were no significant differences in CP, ash, IVOMD, nitrate or oxalate, between the Texas and the Saskatchewan lines, at either stage of maturity with one exception; the Texas line had a significantly lower oxalate content on September 23 (Table 2).

Table 2. Effect of maturity on the composition of Texas and Saskatchewan kochia grown near Swift Current, Saskatchewan in 1987.

Line	CP	Ash	IVOMD	Oxalate	Nitrate
	- - - - - - - - - -		% of DM	- - - - - - - - - -	
August 10, 1987[1]					
Texas	12.6	12.2	51.8	2.5^{b}[2]	trace
Saskatchewan	11.1	11.2	50.9	2.2^{ab}	trace
September 23, 1987[1]					
Texas	7.5	9.4	45.8	1.8^{a}	trace
Saskatchewan	8.4	9.8	47.5	2.8^{b}	trace
Significance of maturity effect	**	**	**	--	--
Significance of line effect	NS	NS	NS	--	--

[1] Harvest Date

[2] Means with the same letter in a column are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test.

Both lines did show a significant decrease in CP, ash, and IVOMD from the August 10 to the September 23 harvest dates. This was similar to what was observed in greenhouse grown plants (Green et al., 1986).

Although the Texas line did not set seed, it did show a similar decline in feed value with increasing maturity.

The production of CP and total digestible nutrients (TDN) as well as the CP content and digestibility, and what the forage will be supplemented with, will help the producer decide when to harvest. Tables 2 and 3 show that although the forage harvested on August 10 had a higher CP content and digestibility, and produced more CP per unit area, it produced considerably less TDN per unit area. If the kochia hay was to be mixed with a good quality hay, the producer should select the higher yield of reasonably good kochia. On the other hand, if the intention was to use it as a protein and energy source and to mix it with a poor quality hay such as slough grass, or a good quality crop residue, the producer may decide he requires the best quality kochia he can get and should select an August 10 or earlier harvest date.

Table 3. Production of dry matter, crude protein and total digestible nutrients from Texas and Saskatchewan kochia grown near Swift Current, Saskatchewan in 1987.

Harvest Date	Texas (kg ha^{-1})			Saskatchewan (kg ha^{-1})		
	DM	CP	DOM	DM	CP	DOM
August 10	5220	660	2370	4770	530	2160
September 23	7250	540	3010	5630	470	2410

A preliminary trial of Texas and Saskatchewan kochia grown in Texas was conducted in 1987. Saskatchewan kochia seed, sent to Adam Nieto in Vega, Texas, was planted in February adjacent to some fall seeded Texas kochia. The Saskatchewan line began to produce seed earlier than the Texas line. Both lines were harvested on August 15, 1987, about the time Texas kochia is normally harvested for hay. Samples were dried and sent back to SRC where they were submitted to the FTL for analyses as described previously. The Texas kochia had a higher feed value than the Saskatchewan kochia, although the Saskatchewan kochia grown in Texas was much higher in feed value than Saskatchewan kochia grown in Saskatchewan (Table 4). The oxalate content of both lines was higher than has been observed in kochia grown in Saskatchewan. There appears to be a direct relationship between the oxalate and CP content of kochia (see Chapter 4).

Table 4. Composition of single samples of Texas and Saskatchewan kochia grown near Vega, Texas in 1987.

Kochia Line	CP	Ash	IVOMD	Oxalate	Nitrate
	- - - - - - - - - - - -	- - - % of DM	- - -	- - - -	- - - - - -
Texas	22.6	14.7	58.7	5.4	trace
Saskatchewan	18.7	13.1	53.7	5.1	trace

The levels of soluble oxalate are above what would be considered toxic and would require dilution with other feed, and supplementation with calcium hydrogen phosphate. Low oxalate accumulating selections of kochia have been obtained by Fuehring and Finkner (1986). These should be tested in Saskatchewan.

The available evidence from this experiment in Saskatchewan and the observation trial in Texas suggest that Texas and Saskatchewan lines of kochia have similar feed vaues when grown in similar environments.

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CHAPTER 14

ALLELOPATHIC (NATURAL HERBICIDE) EFFECTS OF KOCHIA ON OTHER PLANTS AND OTHER PLANTS ON KOCHIA

by

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ABSTRACT

When kochia is grown after kochia in a crop system on saline soil farmers have observed that it is frequently stunted, yellow and crowded. A field experiment near Moose Jaw in 1987 (see Chapter 5) demonstrated that soil cultivation in early spring substantially increased height, greenness and yield. When combined with evidence from other researchers, it appeared that spring cultivation helped destroy allelopathic chemicals (natural plant herbicides) left in the soil from the previous year's kochia crop, as well as reducing the number of plants per unit area.

Aqueous extracts of kochia and of brome-crested wheatgrass, and of manure from animals fed kochia or grass hay, severely inhibited the growth of kochia seedings in an agar growth medium. When kochia, or grass hay, or the manure from these hays were incorporated into soil, most of these materials, either freshly incorporated or kept for 30 days in soil did not hinder the growth of kochia. Only kochia manure, after decomposing in the soil for 30 days, had an inhibitory effect on kochia seedling growth.

Phenolic acid and flavonol were suspected by previous researchers to be the natural herbicide factors in kochia plant debris which might hinder the growth of new kochia seedlings. The concentration of phenolic acid in kochia increased until early flower after which it decreased in one experiment but not in another. Flavonol, on the other hand, increased in concentration after flowering. Procedures were

developed for separating phenolic acid from flavonol. The next stage planned is to test various of these phenolic acid or flavonol extracts for their effect on kochia seedling growth, and also to test whether soil cultivation helps decrease their concentration in the soil.

Greenhouse experiments at Swift Current showed that kochia grew poorly in soil which had been growing flixweed (Descurainia Sophia (L.) Webb) or stinkweed (Thlaspi Arvense L.) in early spring. These two mustard family (Brassica family) spring annual weeds were suspected of containing allelochemicals which inhibited kochia seedling growth. Two cultivated non-weedy Brassicas, canola and mustard (Brassica napus and Brassica juncea respectively) were tested for the ability of young plants of these species to inhibit the growth of kochia. Both species greatly reduced the growth of kochia; canola reduced germination, mustard reduced the growth of young plants. Further experiments are planned to evaluate the use of young brassica plants as green manures to control not only kochia but other weeds as well.

INTRODUCTION

Naturally occurring chemicals (allelochemicals) in kochia plant debris can be leached into the soil in the fall and inhibit the growth of certain crops next year. Crops that can be affected include kochia itself (Lodhi, 1979), sorghum and soybean (Einhellig and Schon, 1982) and blue grama grass (Karachi and Piper, 1987). Thus it was important to learn how to control and decrease the effect of these natural herbicides if kochia were to be used in crop rotations on saline soil.

Kochia produces very large amounts of seed, and in the second year of growth on a site, a dense covering of tiny plants could be observed (Table 1, from Iverson and Wali, 1981).

Table 1. Frequency, biomass, density and height of wild kochia plants during the first three years of growth on reclaimed land from surface mining of lignite coal (Iverson and Wali, 1981).

Years after mining	Frequency %	Biomass g m^{-2}	Density plants m^{-2}	Height cm
1	100	222.5	52	53.7
2	98	70.8	10464	11.3
3	10	0.01	5	0.2

Note: soil not cultivated in any year.

Even when the dwarfed tiny plants in year 2 were thinned to a density of 50 plants m^{-2}, they did not grow well (Iverson and Wali, 1981). This was strong evidence that a chemical in the soil, not crowding, was responsible for the dwarfing effect in year 2. Growth chamber experiments showed that decaying kochia leaves and roots inhibited the growth of kochia but did not inhibit wheatgrass or sweetclover (Iverson and Wali, 1981).

Lodhi (1979) isolated phenolic acids (caffeic acid, chlorogenic acid, ferulic acid) and flavonols (myricetin and quercitin) from kochia leaves, and showed that they were toxic to the growth of young kochia seedlings. The concentration of the substances in kochia was not measured, nor the effect of stage of maturity, so it was not possible to decide which substances were most affecting growth of following crops.

Einhellig and Schon (1982) showed that late season (November) stalks of mature kochia contained water soluble substances which inhibited the growth of sorghum and soybeans. Some or all of phenolic acids, flavonols, betalains, alkaloids or saponins in kochia might be involved in this herbicide effect (Einhellig and Schon, 1982).

The objectives of the present studies were the following:

1. Test whether soil disturbance in the spring would improve the yield of kochia following kochia.
2. Test whether Saskatchewan kochia contained substances which inhibited the growth of young kochia.
3. Evaluate whether the manure from animals fed kochia was more or less toxic to young kochia than kochia forage, i.e. was digestion by cattle changing the plant toxicity contained in kochia?
4. Measure changes in suspected natural herbicides in kochia with stage of maturity.

5. Identify, if possible, which compounds in kochia were natural herbicides.

The growth of kochia is inhibited by mustard family plants. Field observations in Texas (Kernan and Green, 1986) showed that wild mustard plants did not usually have wild kochia growing close to them. This was also observed in fields near Swift Current in 1986. These field observations were followed by greenhouse and growth experiments to confirm that natural herbicides were present, and that canola and tame mustard contained these natural herbicides (allelopathic chemicals) also. This could be the initial stages in developing a cover crop which would suppress weeds, including wild stands of kochia where they were not wanted.

MATERIALS AND METHODS

1. Effect of Soil Disturbance on Kochia Yield.

The details of this farm demonstration are given in Chapter 5. The trial was designed to test the effects of early spring cultivation, thinning of plants in late spring, and fertilizer, on the yield and feed value of kochia. The site had grown kochia for at least two years previously.

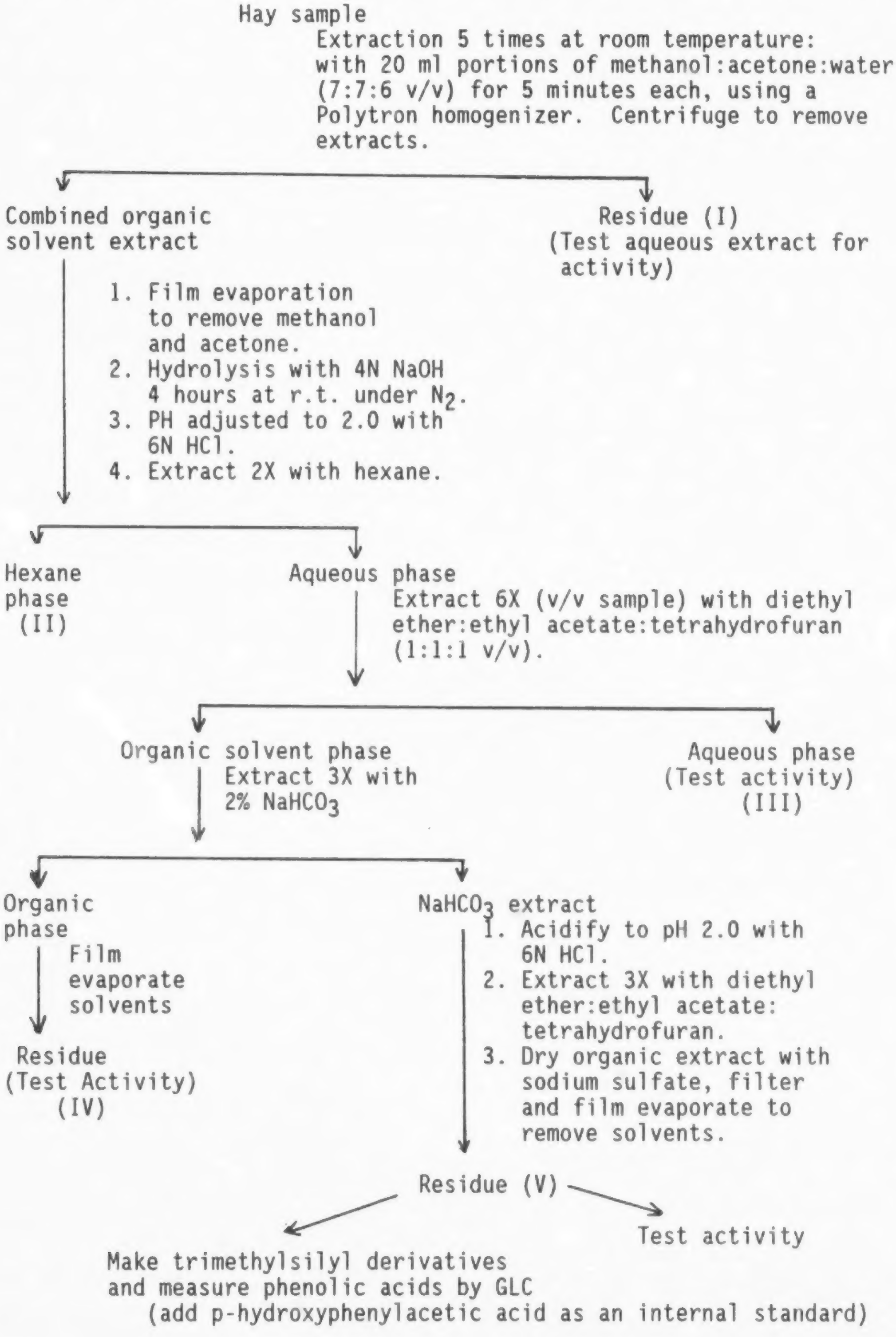
2. Stage of Maturity Effects on the Composition of Kochia, Including the Amounts of Phenolic Acid, Flavonol, and Saponin, Possible Contributors to the Natural Herbicide Affects of Kochia.

The methods used and results obtained are described in Chapter 13. of this report, and in more detail in the separate publication R-814-2-E-88 (K. Sosulski, 1988).

3. Separation of Phenolic Acid from Plant Extracts of Kochia Forage.

The procedure used was a modification of the procedure of Dabrowski and Sosulski (1984). Free and esterified phenolic acids were extracted together from dried kochia hay (late bud - early flower) with methanol: acetone:water (Figure 1). Organic solvents were removed by film evaporation. The aqueous residue was hydrolyzed with 4N sodium hydroxide, 4 hours at room temperature (under a nitrogen atmosphere). The hyrolysate was acidified with 6N hydrochloric acid (to pH 2.0) and extracted first with hexane (to remove lipids) and then with diethyl ether:ethyl acetate:tetrahydrofuran (1:1:1 by volume).

Figure 1. Method used to isolation phenolic acids from kochia hay.



Hay sample

Extraction 5 times at room temperature: with 20 ml portions of methanol:acetone:water (7:7:6 v/v) for 5 minutes each, using a Polytron homogenizer. Centrifuge to remove extracts.

Combined organic solvent extract

Residue (I) (Test aqueous extract for activity)

1. Film evaporation to remove methanol and acetone.
2. Hydrolysis with 4N NaOH 4 hours at r.t. under N_2.
3. PH adjusted to 2.0 with 6N HCl.
4. Extract 2X with hexane.

Hexane phase (II)

Aqueous phase

Extract 6X (v/v sample) with diethyl ether:ethyl acetate:tetrahydrofuran (1:1:1 v/v).

Organic solvent phase

Extract 3X with 2% $NaHCO_3$

Aqueous phase (Test activity) (III)

Organic phase

Film evaporate solvents

Residue (Test Activity) (IV)

$NaHCO_3$ extract

1. Acidify to pH 2.0 with 6N HCl.
2. Extract 3X with diethyl ether:ethyl acetate: tetrahydrofuran.
3. Dry organic extract with sodium sulfate, filter and film evaporate to remove solvents.

Residue (V)

Make trimethylsilyl derivatives and measure phenolic acids by GLC (add p-hydroxyphenylacetic acid as an internal standard)

Test activity

The organic solvent phase was extracted three times with 2% sodium bicarbonate to remove phenolic acids (and other organic acids). The bicarbonate extracts were acidified with 6N hydrochloric acid, to pH 2.0. The acidified aqueous phase was extracted with diethyl ether:ethyl acetate:tetrahydrofuran to recover phenolic acids. For gas-liquid chromatography, the trimethylsilyl derivatives were prepared, as described by Dabrowski and Sosulski (1984).

4. Effect of Kochia or Grass Hay, or the Manure from Steers Fed These Hays, on the Germination and Early Growth of Kochia Seeds

4.1 Effect of aqueous extracts on kochia seeds grown on agar plates.

The feeding trial with steers is described in Chapter 7. The faeces and urine from animals fed 60% kochia hay:40% grass hay or 100% grass hay (a brome grass:crested wheatgrass mixture) were collected, and urine and faeces samples combined in the ratio as excreted by the animals.

The manure samples and the hay samples were each extracted twice with water at room temperature, and filtered. The filtered extracts were then sterile filtered. The sterile extracts were mixed with 1.2% Difco bacto agar to give final concentrations of medium with 1:100, 1:200 and 1:300 dilutions based on the original hay. The manure dilutions were corrected for the dry weight of manure excreted per unit weight of hay consumed.

The agar plates were prepared according to the procedure of Pederson (1986). Kochia seeds were rinsed thoroughly with sterile water before placing on the agar plates for the germination tests.

4.2 Effect of kochia hay:grass hay (60:40) or grass hay or their manures on the early growth of kochia seedlings grown in soil.

Materials from the same feeding trial (Chapter 7) were used. The mixed hay or the grass hay (ground to pass a screen) were mixed with a light potting soil mixture (non-sterilized) to give an amount of hay in the soil equivalent to a 4000 kg ha^{-1} yield of hay incorporated into the soil. The manures from animals fed these hays were mixed in soil in an amount equivalent to the dry weight output of excreta (faeces plus urine) per unit intake of hay.

The soil mixture was watered to 80% of field capacity. Mixtures were then seeded with kochia seed immediately or after incubating the soil mix for 30 days at room temperature. (The soil mix was placed in 20 cm diameter (314 cm^2 area) plastic pots prior to seeding). After the kochia had emerged, the seedlings were thinned to 5 seedlings pot^{-1}. The seedlings were grown in a growth room (20°C during light and dark periods) for 30 days. Plants heights were measured, and harvested plants were dried overnight at 60°C and weighed.

5. Field observations on the effect of stinkweed and flixweed on the growth of kochia

The description of the trial is given in Chapter 11.

6. Experiments to measure the effect of plant debris from young canola and mustard plants on the germination and early growth of kochia.

Experiment 1

Effect of young canola plants debris on the germination and early growth of kochia.

Canola seeds were planted in a sand-soil mixture on November 30, 1987 and grown for two weeks at room temperature (~20°C). The roots were left in the soil after harvesting and the tops were dried and retained.

On January 7, 1988, four kochia seeds were planted in each of six, 4 cm square (16 cm^2 area) pots containing the canola roots. The dried canola residue was evenly spread over the surface of the soil. The time interval between harvesting the canola and planting the kochia was 23 days.

Another six pots were planted with four kochia seeds per pot and poplar mulch was spread evenly over the soil surface (for shading effect). A third set of six pots were also planted with four kochia seeds per pot with no residue on the soil surface.

All kochia seeds used were from one kochia plant harvested in Saskatoon, on October, 1986. These seeds had 98% germination.

The number of kochia seedlings per pot was counted after one week. The plants were thinned to two plants per pot, then grown for another two weeks at 25°C. They were watered daily to 80% field capacity. Measurements of plant height were taken on January 20 and 27, 1988. After harvest, on January 28, wet weights were taken per pot and the plants were oven dried overnight at 60°C.

Experiment 2

Comparison of the effects of canola (B. Napus Cv. Westar) and mustard (B. juncea Cv. Domo) on the germination and early growth of kochia.

Canola (4 plants per pot) and mustard (4 plants per pot) were seeded and grown in a sandy soil mixture in 15 cm diameter (177 cm^2 area) plastic pots for 26 days until the plants were approximately 20 cm tall and had formed a complete leaf canopy over the pots (26 days from seeding). The plants were grown in a growth chamber with a 12 hour light period and a temperature of 20°C. Plants were grown under fluorescent lights supplemented with incandescent lights.

Canola and mustard plants were cut off at ground level and weighed. Twenty seeds of kochia (98% germination) were planted 1 cm deep into each pot (5 replicates of each treatment). The canola or mustard top growth from each original pot was cut into 3-5 cm long pieces and laid evenly on the surface of each pot.

Two sets of control pots were each planted with kochia (20 seeds each). Poplar shavings (6 g pot^{-1}) were placed on the surface of one set of controls. The other set was left without surface mulch.

Pots were watered each day with tap water to 80% of field capacity. Care was taken to avoid soil disturbance while watering.

After one week, the number of kochia seedlings in each pot was counted. The kochia was thinned to 5 seedlings per pot where necessary, and growth continued for a further three weeks. Plants were harvested, and fresh and dry (forced air oven at 30°C overnight) weight recorded.

RESULTS AND DISCUSSION

1. Effects of Soil Disturbance on Kochia Yield

The results of the field trial are summarized in Table 1 (see also Chapter 5).

Table 2. Effects of spring cultivation, soil disturbance in late spring to thin plants, and nitrogen fertilizer on yield of kochia.

Treatment	Yield (g m^{-2})
Spring Cultivated	
Soil disturbance to thin plants	
No fertilizer	813
50 lbs N fertilizer	1665
100 lbs N fertilizer	1184
No soil disturbance to thin plants	
No fertilizer	741
50 lbs N fertilizer	856
100 lbs N fertilizer	965
Not Spring Cultivated	
Soil disturbance to thin plants	
No fertilizer	682
50 lbs N fertilizer	794
100 lbs N fertilizer	844
No soil disturbance to thin plants	
No fertilizer	544
50 lbs N fertilizer	872
100 lbs N fertilizer	947

Soil disturbance, thinning plants after establishment and nitrogen fertilizer all had a positive effect on kochia yield. In mid season the effect was visually very marked (see photo 5 in the executive summary). Plants from disturbed soil were noticeably taller and more vigorous.

Further trials to confirm this effect are needed under replicated, randomized experimental conditions.

2. Stage of Maturity Effects on the Composition of Kochia

The results from two experiments are shown in Table 2 (taken from Sosulski, 1988). The changes in concentrations of phenolic acid, phenol and saponin were inconsistent between experiments. Flavonol showed a tendency to increase in concentration up to the early fruiting stage. Differences in concentration of some antinutritive constituents may reflect the degree of retention of mature seed. In 1985 most seed was lost (shattered) before the mature forage was harvested.

Phenolic acid declined much more rapidly after flowering in 1985 than in 1986.

It is unknown at the present time whether differences between experiments represent the effects of different growing environments (Swift Current in 1985, Saskatoon in 1986) as well as different plant accessions (wild local seed in both cases).

Table 3. Effect of stage of maturity of good quality kochia on anti-nutritive constituents of forage.

Stage of maturity	Total phenolic acid mg g^{-1}	Total phenol mg g^{-1}	Flavonol mg g^{-1}	Tannin mg g^{-1}	Saponin HA g^{-1}
	Harvested in 1985 (Swift Current, saline soil)				
Early Bud	8.58	9.70	0.77	0.61	1.46
Bud	20.40	11.13	1.04	0.24	1.43
Flower	16.43	11.60	3.18	0.41	2.01
Early Fruit	2.28	11.20	6.75	0.40	2.93
Mature Fruit	1.67	10.70	4.25	0.93	1.88
	Harvested in 1986 (Saskatoon, non-saline soil)				
Early Bud	9.99	3.02	1.03	0.35	1.31
Bud	12.84	3.27	0.99	0.68	1.62
Early Flower	11.16	4.14	4.07	0.38	6.70
Flower	8.77	4.40	7.39	0.69	2.22
Early Fruit	16.22	4.30	4.69	0.73	3.76

Assuming no experimental errors, these data imply that the anti-nutritive factors such as phenolic acids, vary not only with stage of maturity, but also with location, environment and/or source of seed.

Individual phenolic acids followed a similar complex pattern. Esterified phenolic acids and bound phenolic acids were similar in magnitude in 1986, each being about 0.5% by weight of the forage at various stages of maturity. Gentisic and protocatechuic acids were the dominant phenolic acids in estified phenolic acids, along with varying amounts of ferulic acid and syringic acid. A number of these have been identified in other studies as being natural herbicides. These same phenolic acids were also the major phenolic acids in th[illegible]und fraction.

In 1985 the kochia grown on saline soil displayed a somewhat different pattern. Gentisic and protocatechuic acids were high in young forage (in both esterified and bound fractions). In addition the bound acid fraction contained various amounts of syringic acid and p-coumaric acids (early stages), and ferulic and isoferulic acids (ferulic increasing with stage of maturity).

These patterns of phenolic acids were very complex and difficult to interpret. We considered that a better strategy was to isolate various fractions and follow their allelopathic (natural herbicide) activity. The beginning of this process is described in the next section.

3. Separation of Phenolic Acids from Plant Extracts

Phenolic acids could be separated quite cleanly by extraction with sodium bicarbonate. The GLC analysis of the bicarbonate extract contained protocatechuic acid, p-coumaric, ferulic, synapic, and small amounts of chlorogenic acid (free and esterified acids from early flower stage kochia).

Studies are now commencing on carrying out the isolation procedure and testing the various fractions for activity against kochia seedlings.

4. Effect of Kochia or Grass Hay, or Manure from Steers Fed These Hays, on the Germination and Early Growth of Kochia

4.1 Aqueous extracts: effect on kochia grown on agar plates.

All extracts, at all dilutions, were quite inhibitory to the growth of kochia seedlings (Table 3).

Table 4. Effect of aqueous extracts of kochia and grass hays, and manures from steers fed these forages on growth of kochia seedlings.

Material	Dilution	Length of kochia seedlings (mm) after 71 hours growth
Control		53.7
grass hay	1:100	20.4
	1:200	24.3
	1:300	26.8
Kochia:grass hay (60:40)	1:100	22.6
	1:200	25.2
	1:300	27.0
Grass hay manure	1:100	20.7
	1:200	25.0
	1:300	26.8
Kochia:grass manure (60:40)	1:100	22.5
	1:200	25.2
	1:300	27.0

Although there was a small decrease in growth inhibition with dilution, aqueous extracts of both hays and both manures were inhibitory to kochia seedlings. Digestion by steers had no effect on the toxicity of the forage extracts. Both hays were of similar toxicity. Addition of kochia hay to grass hay had little effect on toxicity.

We considered that this test may have been misleading in that no soil was present. Soil particles can absorb various plant constituents, and soil microorganisms can convert, and/or destroy phenolic acids and other plant components. Therefore the soil experiment reported next was considered a better test of field effects.

4.2 Effect of kochia hay:grass hay (60:40) or grass hay, or their manures, on the early growth of kochia in soil.

None of the materials inhibited the growth of kochia in soil when they were freshly incorporated in soil (Table 4). When the materials were allowed to decompose in the soil for 30 days before kochia was planted, only kochia:grass hay manure had a significant inhibitory effect (Table 4). This result was unexpected and this experiment should be repeated. If this result is confirmed, the experiment should be extended to evaluate longer periods of decay in the soil to determine how long it takes for the inhibitory effect of kochia manure to decay away.

Table 5. Effect of residue and manure treatments on kochia height and yield.

Treatment	Fresh soil		30 day soil	
	Height (cm)	Yield (g pot^{-1})	Height (cm)	Yield (g pot^{-1})
Control	15.3	3.44	64.0^{c}	2.67^{b}
Kochia hay	16.2	3.26	14.7^{b}	3.36^{c}
Grass hay	14.9	2.89	15.8^{b}	3.34^{c}
Kochia manure*	13.9	3.44	10.6^{a}	1.52^{a}
Grass manure	14.2	4.05	14.0^{b}	3.19^{bc}
Significance of treatment effect	NS	NS	**	**

Means with the same superscript in the same column are not significantly different at the 5% level according to Duncan's Multiple Range Test.

* Animals fed kochia hay:grass hay in a 60:40 ratio.

5. Field Observations on the Effect of Stinkweed, Flixweed and Kochia on the Growth of Kochia

Field observations of kochia-weed interactions suggested weeds such as flixweed and stinkweed might inhibit kochia establishment. To test this hypothesis, soil (top 0-5 cm) was collected from sites growing specific plants and placed in flats for greenhouse testing. Soil from sites containing flixweed, stinkweed, kochia, wheat stubble, foxtail barley, quackgrass, or silverweed (Potentilla anserina) was levelled in seeding flats, and compacted prior to seeding with Saskatchewan kochia (600 seeds/square yd). The flats were watered. Measurement on seedling emergence and growth were taken at regular intervals. Several interesting observations were made. Kochia established slowly on kochia, flixweed or stinkweed contaminated soils. Quackgrass, foxtail barley, silverweed and wheat stubble were not detrimental to kochia establishment. These observations confirmed the field observations. Kochia has already been reported to be autoallelopathic (Lodhi, 1979). The desirability of planting kochia in the correct crop rotation is obvious. It may be difficult to continuously crop kochia, although this has been done in Texas. Possibly this is related to the fact that in 1986 the later seeding dates yielded the highest (see Chapter 13). No difficulties should be encountered in foxtail barley contaminated soil if these results prove to be correct.

Soil disturbance may also have a beneficial effect on removing allelopathic inhibitors from the soil. A number of observations in Texas and New Mexico imply that some degree of soil disturbance is important to control kochia plant numbers and remove soil phytotoxin. With soil disturbance each year at planting, it appears possible to grow kochia on the same site for at least several years in a row (Durham and Durham, 1979, and 1986 field trip to Texas).

This preliminary experiment is consistent with field observations of Mr. K. Lepoudre, Saskatchewan Agriculture, Regina, Saskatchewan (phone call to E.Coxworth, September 5, 1986). On saline sites (cultivated soil) which were sprayed in the fall with 2,4-D to control winter annuals (such as flixweed and stinkweed), a good stand of kochia established well in the early spring and grew vigorously. On sites not sprayed in the fall with 2,4-D, winter annuals grew vigorously and kochia growth next spring was sparse and poor.

These observations suggest that winter annuals and early spring germinating weeds must be controlled if a good stand of kochia is to be obtained.

6. Experiments to Measure the Effect of Plant Debris from Young Canola and Mustard Plant on the Germination and Early Growth of Kochia.

Experiment 1. Effect of young canola plants

The oven dry weight of the canola residue, which was spread over the soil surface, was 0.37 g pot^{-1}. An equal amount of poplar shavings were used on one set of the controls.

The canola residue significantly ($P<0.05$) reduced kochia germination. The effect of canola residue on subsequent kochia was less, but still significant after 21 days growth, of the plants which has germinated (Table 5).

Three weeks had elapsed after the canola was harvested, before this allelopathic experiment was started. The canola roots were kept moist during this time. The active allelopathic agent may have only been present in low concentrations since the canola roots and residue reduced yield of plants which germinated by only 29% (Table 5). It is possible that biological degradation took place in the soil, but if this occurred in three weeks, activity might decrease substantially in the field where the allelopathic chemicals would have several months to be degraded.

Table 6. The effect of canola residue on kochia growth.

Treatment	Height (cm) Jan. 27/88	Yield ($g\ pot^{-1}$)	Germination (%)
Control 1[1]	3.3	0.082	100
Control 2[2]	2.6	0.082	100
Canola Residue	2.6	0.058	29
Significance of treatment effect	NS	**	**

[1] control with poplar
[2] control with no residue

Experiment 2. Comparison of canola and mustard plant effects on growth of kochia.

When the Brassica plants were cut and spread on the soil surface to measure the phytotoxic effect, a strong smell was detected. This may indicate that some of the toxic material was leaching off the plants into the air, reducing the phytotoxic effect. Incorporating the Brassica residue (in future experiments) into the top 5 cm of soil may limit the loss of these vapors. It is known that indolylacetonitrile (from *B. napus*) and allyl isothiocyanate (from *B. juncea*) are very volatile (I. McGregor, personal communication).

Even with the Brassica plants spread loosely on the soil surface in the present study there was a significant phytotoxic effect on the kochia plants. The lower yields and % germination show how the kochia plants are effected by the Brassica species tested (Table 6).

Table 7. The effect of B. napus and B. juncea on kochia germination and growth.

Treatment	Germination (%)	Height at harvest (cm)	Air dry weight (g pot^{-1})	Air dry weight (g plant^{-1})
B. napus	22^a	13.1^b	1.1^a	0.5^b
B. juncea	64^b	9.0^a	1.3^a	0.3^a
Poplar	92^c	15.3^c	4.0^c	0.8^c
No residue	88^c	15.5^c	3.2^b	0.6^{bc}
Significance of effect	***	***	***	***

Means within a column with the same superscript are not significantly different according to Duncan's Multiple Range Test ($P<0.001$).

It is noteworthy that the effects of B. napus and B. juncea were different. B. napus inhibited germination more than B. juncea, where B. juncea had a more negative effect on the growth of plants. Both soil incorporation, and testing of mixed populations of the two Brassica species should be tested next.

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CHAPTER 15

IRRIGATION AND REGROWTH OF KOCHIA AFTER CUTTING

by

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ABSTRACT

The yield of Saskatchewan kochia grown under irrigation at Swift Current, Saskatchewan, on non-saline soil was 8360 kg DM ha^{-1} (one cut), not significantly different from the non-irrigated yield of 7740 kg DM ha^{-1}. Rainfall in the crop year of 1987 was high enough to obviate the need for irrigation in this particular trial.

A demonstration trial with Texas kochia on saline soil on the farm of Mr. Ray Derdall at Outlook, Saskatchewan, in 1987 gave a yield of 4460 kg DM ha^{-1} (first cut) and 3790 kg DM ha^{-1} (second cut). Planting density was high (450 plants m^{-2}) and this helped keep stems small. The site was so saline that conventional crops tried previously on the site had yielded poorly, or had been excessively expensive to grow. Soil available nitrate was very high prior to the kochia study, and this may be the reason why kochia protein and nitrate were both high in the harvested hay. A hay preservative was used with good results to bale kochia hay at 25-28% moisture. Texas kochia (uncut) was over 2.2 meters (7'4") high in late October and still had not produced viable seed.

INTRODUCTION

Kochia (Kochia scoparia L. Schrad) has been grown under irrigation in New Mexico and high yields of forage have been achieved (Fuehring, 1981, 1984). Using a single cut system, managing plant populations by thinning (by listing type cultivation), and providing nitrogen fertilizer, yields were 12280 kg DM ha^{-1} (equivalent to 6.6 tons per acre, hay basis of 17% moisture) (Table 1). In subsequent research, multiple cuts were taken and even higher yields were obtained. Plants were cut at 10 cm (4") above ground to retain some leaves on the stubble to encourage regrowth. Yields varied by year of production, nitrogen fertilizer rate and frequency of application, irrigation amount and frequency, and number of clippings. Yields in 1978 were as high as 25.6 tonnes DM ha^{-1} with three irrigations, 280 kg N ha^{-1}, and four clippings. Yields were surprisingly insensitive to plant populations. Yields ranged from 15.0 to 18.5 tonnes DM ha^{-1} over a plant population of 64-1540 plants m^{-2}. A seeding rate of 1 kg ha^{-1} (about 1 million seeds) was considered adequate with good germination conditions. At least three cuttings per year were needed to ensure that plant stems did not become too thick and woody.

Measured water use (Fuehring, 1984) was about one-third that of alfalfa, so where water supplies were scarce, kochia was considered to have considerable potential.

The objectives of the present experiments were three.

1. Compare kochia yield with irrigation compared to dryland on non-saline soil, and with one cut,
2. measure kochia yield with irrigation on saline soil and,
3. determine if plants would regrow after a first cutting.

Table 1. Yield of kochia forage as affected by irrigation number, nitrogen application and thinning (by listing), Plains Branch Station, 1980 (from Fuehring, 1981).

Treatment		Yield of Forage (tons ac^{-1} at 17% moisture)						
Applied N lb ac^{-1}	Listing yes or no	None	Prewater only	Prewater + June	Prewater + June & Aug.	Average	Average for N	Average for ± listing
		- - - - - -	- - - irrigations	- - -	- - - - - -			
0	-	2.2	2.0	2.1	2.7	2.3	2.7	3.7
0	+	2.8	3.8	2.7	3.5	3.2		4.3
100	-	2.8	4.0	4.1	4.8	3.9	4.2	
100	+	3.2	4.8	5.1	4.8	4.5		
200	-	3.7	4.2	5.4	6.4	4.9	5.1	
200	+	3.6	4.8	6.2	6.6	5.3		
Average		3.1	4.0	4.3	4.8	4.0		
LSD$_{0.05}$					0.5	0.3		
LSD$_{0.05}$ for irrigations		0.6						

MATERIALS AND METHODS

Irrigation trial at Swift Current on non-saline soil.

Local Saskatchewan kochia seed was planted on 14 May, 1986 on non-saline soil (South Farm, Agriculture Canada, Swift Current). The seeding rate was 3.4-4.5 kg ha^{-1} (3-4 lbs ac^{-1}). Seed was metered onto the surface, packed with a seed drill, followed by a harrowing operation. The experimental design was randomized with four replicates. Guard strips of winter wheat were planted between kochia treatments to separate irrigated and non-irrigated plots and prevent irrigation water drifting from irrigated to non-irrigated plots. Plots were irrigated on 25 and 30 June, 2 and 17 July, with a total of 15.5 cm (6.1") of water. Plots were harvested on 4th August.

Demonstration trial at Outlook, Saskatchewan (R. Derdall) on saline soil.

The complete details of the demonstration procedures are given in Mr. Derdall's report (Derdall, 1988).

Texas kochia seed (from A. Nieto, Vega, Texas) was seeded on 26 May, 1987. The site had grown a very poor stand of barley the previous year. The soil on the site was measured to have a salinity of 7.9-8.3 mS cm^{-1} (severely saline). The soil was cultivated several times before seeding.

The seed was planted at 3.4-4.5 kg ha^{-1}, after a shower so that the soil was damp. A grass seeder was mounted on the rear of a Massey Ferguson press drill with 15 cm (6") spacings. The drop spouts from the grass seeder were located just to one side of the coulters of the press drill. When seeding, the coulters were put into the ground and allowed to turn. As the coulters turned they threw a fine blanket of dirt over the kochia seed. The day after seeding, the field received 1.5 cm (0.6") of rain.

Prior to seeding, one-half the field was fertilized with 48 kg P_2O_5 ha^{-1} (42 lbs ac^{-1}) banded with a press drill to a depth of 11-12 cm.

The whole field was irrigated on June 11 and July 12, each time with 12.7 cm (5") of water. The first cut was taken on July 27 when most plants were still pre-bloom. The height of plants was about 100 cm (40") and stalk size was about 0.80 cm (0.31"). The forage was cut with a New Holland Haybine and gave an excellent crimp. Windrows were made wide to hasten drying. Plants were cut 20 cm (8") above ground with many leaves left on the stubble to encourage regrowth.

Rainfall prior to the first cut was 17 cm (6.75"). Rainfall after the first cut and prior to the second cut on 25 September was 8.3 cm (3.25"). No irrigation was applied during the second growth interval. The kochia was 91 cm (36") tall at the second cut.

The kochia swath was baled with a New Holland large round baler at a hay moisture content of 25-28%. A hay preservative (Silo King Plus) was applied at a rate of 0.45 kg (1 lb) per bale.

Part of the field was left uncut to observe flowering and seeding of the Texas kochia.

RESULTS

Irrigation trial at Swift Current.

Yield of kochia hay (DM) with irrigation was 8360 kg ha^{-1}, and without irrigation was 7740 kg ha^{-1}. The yield differences were not significant. Apparently natural rainfall and temperatures were such that irrigation did not give any yield benefit at this location. Rainfall during the growth period was 12.9 cm (5.0") and this may have been sufficient to provide dryland kochia was as much moisture as was needed.

Irrigation and regrowth demonstration at Outlook.

Yields are shown in Table 2.

Table 2. Yields of irrigated kochia from two cuts (Outlook, 1987).

Treatment	Yield		
	tonnes ha^{-1}	tons acre^{-1}	
	DM	DM	15% moisture
1st Cut	4.45	1.99	2.29
2nd Cut	3.79	1.69	1.94
Total	8.25	3.68	4.23

Natural rainfall at the Outlook site was 25 cm (10") during the growing period of 26 May to 25 September, about the same as the irrigation water supplied.

Leaving a stubble height of 20 cm (8") after making the first cut permitted a good regrowth, and the second cut yield (Table 2) was almost as high as the first cut.

Use of the hay preservative gave good control of hay spoilage, even through the hay was baled at 25-28% moisture.

The feed value of the first cut kochia hay is shown in Table 3.

Table 3. Feed value of kochia hay grown under irrigation with or without phosphate fertilizer at Outlook in 1987 (% of DM).

	Kochia, unfertilized	Kochia, P_2O_5 fertilized
TDN	58 - 60	59 - 61
Calcium	0.89	1.02
Phosphorous	0.34	0.40
Crude protein	24.2	25.6
Nitrate	5.3	3.4
Crude protein - corrected for nitrate	16.7	20.8

Although not done as a replicated experiment, phosphate fertilizer appeared to have a beneficial effect on reduction in nitrate and increase in nitrate-free crude protein. Replicated experiments need to be done on the effect of N to P_2O_5 ratios and their effects. While the final report from Derdall and the Saskatchewan Water Corporation was not available at the time of writing, the initial verbal information was that available soil nitrate at the site prior to growing kochia was 206 kg NO_3 N ha^{-1}. This very high soil nitrate, relative to phosphate applied, may have driven kochia nitrate accumulation to these very high levels (Henry, 1988; Duncan, 1988). Growth room experiments have been designed to test this hypothesis. No visual yield differences were noted with the use of phosphate fertilizer.

According to Derdall (personal communication to E. Coxworth, 30 June, 1988) this kochia hay was fed at about 25% of the diet with alfalfa hay to pregnant beef cows. Over the winter feeding period the animals gradually increased their intake of kochia and were eating up to 50% at the end of winter. At this level, some animals were showing signs of diarrhea. The animals were otherwise normal and produced normal healthy calves.

Sherrod (1973) demonstrated that when kochia hay was combined with at least 50% alfalfa hay, the nitrogen retention was greatly improved over diets with greater than 50% kochia. The same observation was made in more recent experiments with kochia and grass hay (see Chapter 7). Thus the act of keeping kochia at less than 50% of a forage appears able to greatly reduce the potential toxicity problem of high nitrate in kochia hay. Further experiments need to be done to confirm these important observations.

SUMMARY

Kochia can be grown under irrigation in Saskatchewan either on non-saline or saline soil. Experiments are needed to compare the water-use efficiency of kochia with other crops under irrigation.

Regrowth of kochia is possible provided the stubble is left high enough after the first cut and (likely) moisture is adequate.

Kochia can accumulate large amounts of nitrate if soil nitrate is high. Fertilizer experiments and animal feeding experiments are needed to determine how best to minimize this problem. Diluting high nitrate kochia feed with alfalfa hay, so that kochia is less than 50% of the diet, appears to reduce potential nitrate toxicity problems.

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